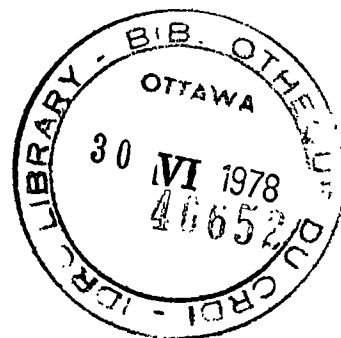


LANDSAT TANZANIA CONSULTANCY REPORT
FOR THE PERIOD AUG. 14 - SEPT. 17, 1977

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LANDSAT TANZANIA PROJECT
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This report includes an outline of the work and discussions undertaken with respect to the IDRC LANDSAT Tanzania Project during the consultancy period August 14 - September 17, 1977. The outline consists of factual accomplishments, descriptions of work in progress, and some personal observations. The report also includes a question about the completion of cartographical work which IDRC will likely be asked to act on in the next few months.

According to contract (March 21, 1977), the requirement of this period of consultancy was "to travel to Dar es Salaam in the Rukwa Region of Tanzania to assist the Bureau of Resource Assessment and Land Use Planning (BRALUP) LANDSAT Project Team in setting up its reconnaissance ground observations, definition of mapping units, and delineation of broad ecological zones". As the report will indicate, this requirement was fully met and several additional tasks accomplished as well. The reported items presented below are arranged more or less by subject matter and not necessarily in the chronological order that they were completed.

Item 1 Visit to Plessey Radar Research Centre,
Havant, Hampshire, PO9 2PE, England

BRALUP maintains ties with the British Remote Sensing Society through which they were introduced to researchers in the remote sensing section of Plessey, a private electronics and telecommunications company whose remote sensing research is highly subsidized by the British Government. Over the past few years Plessey has been involved in the development of a digital image processor and intends to begin marketing it in the next year or so. This processor, known as the IDP 3000, is comparable in many

respects to the IMAGE 100 system at the Canada Centre for Remote Sensing (CCRS) currently being employed in the LANDSAT Tanzania Project. As one might expect, Plessey feels that their system will be superior to the IMAGE 100 system built by General Electric and the other digital image processors now on the market.

A LANDSAT computer compatible tape (CCT) from the Rukwa Region of Tanzania (Scene No. 81049072515) was taken to Havant to make a comparison for future Tanzanian reference. Mr. Owen E. Morgan, Director of the Plessey Remote Sensing and Image Analysis Unit, very kindly provided time and documentation (examples in Appendix A) for a technical discussion of the IDP 3000 system. An attempt was made to load the Rukwa CCT into the system. Unfortunately the attempt was not successful because, while the CCT was in normal NASA format, the IDP 3000 system is capable of accepting British formatted CCTs only at this time. The demonstration proceeded using pre-loaded CCTs.

At the present time and in the present configuration the IDP 3000 system is not superior to systems such as the IMAGE 100. However, it will be if the Plessey researchers are able to build in their planned spatial and textural algorithms. That is, in addition to the multispectral data characteristic of LANDSAT and other imagery, spatial and textural features of an image will be used for interpretation in a manner similar to air photo interpretation. These impressions were conveyed to the BRALUP LANDSAT Project Team.

Item 2 LANDSAT-C Applications Notice

LANDSAT-C is planned for launch in late 1977 or early 1978. Imagery from this satellite will be readily available for users whose areas

of interest fall within the range of one of the existing ground receiving stations. Users whose areas of interest fall outside these ranges, e.g. Tanzania, will be required to submit requests for special coverage. The NASA Applications Notice outlining the information required for such a request was delivered to BRALUP and brief discussions held concerning the acquisition of Tanzanian LANDSAT imagery in the future.

Item 3 Delivery of LANDSAT Imagery

The last purchase of Tanzanian LANDSAT imagery made through Laurentian University/IDRC was delivered to BRALUP. This imagery was in the form of 70 mm positive "chips" compatible with the I²S additive colour viewer purchased for the LANDSAT Tanzania Project. Except for the CCTs of Rukwa and related documentation all of the LANDSAT images that were purchased through Laurentian University/IDRC are now in BRALUP's hands.

Item 4 Equipment

The equipment that was ordered and received by BRALUP for the LANDSAT Tanzania Project was inspected and is in satisfactory working order. Unfortunately all of the equipment that was ordered has not been delivered (see copy of telegram in Appendix B). Particularly annoying is the non-arrival of the densitometer.

Item 5 Map and Report Preparation

The Rukwa field work is progressing more slowly than anticipated and will not likely be fully completed until November, 1977. As a result,

BRALUP has not yet given adequate consideration to the forms in which the project's data and interpretations will be reported. After some prodding a tentative list of maps were identified as being pertinent to the project report or reports and is included here.

<u>Scale</u>	<u>Theme</u>
1: 500,000*	Surface Hydrology Land Systems & Regions/Soils Vegetation
1: 500,000 or 1: 1,000,000	Land Suitabilities** a) village agriculture/crops b) parastatal farming & ranching c) refugee settlements d) forestry & wildlife
1: 1,000,000 or 1: 2,000,000	Slope Altitude Geology Rainfall (Mean Annual) Rainfall Probability Village Settlements

* Given the nature of the LANDSAT imagery over Rukwa Region and the amount of field data being gathered, BRALUP has wisely considered using a scale of 1: 500,000 for the three principal maps instead of the originally proposed scale of 1: 250,000. It should also be noted that a Land Use map is not listed as the LANDSAT imagery that exists for Rukwa Region is not capable of providing a solid data base for such mapping.

** These may appear as separate maps or combinations. For, example, the village agriculture/crops maps could appear as a series of land suitability maps of separate crops, i.e. one for maize, one for rice, etc., if sufficient data is acquired.

With respect to the writing of reports, primary responsibilities will be: hydrology and climate - J. Ngana; land systems, slope, geology, etc. - B. King; soils - C. Rombulow-Pearse and B. King; vegetation - I. Kikula; land suitabilities - BRALUP project staff. Again, unfortunately, BRALUP has not yet considered whether there will be a single project, or several volumes dealing with the separate themes.

Item 6 Vegetation Mapping

A great deal of time was spent with I. Kikula examining his field notes and his field comparisons with the data on ground cover provided by the IMAGE 100 analysis undertaken earlier at CCRS. On the basis of these discussions a programme of supervised and unsupervised analysis with the IMAGE 100 system was drawn up to be completed at CCRS in the period October 12 - 18, 1977. The work in this area of the project will be fully detailed in the report due at the end of October.

Item 7 Soil Classification and Description

At the present time BRALUP does not have a staff member with the knowledge and skills to undertake a proper soil survey. Fortunately, however, they have secured the co-operation of the Uyole Agricultural Centre (Mbeya) for this purpose. While this Centre primarily provides teaching and extension services it also has a small capacity for field research. In addition, Rukwa Region does fall within their sphere of responsibilities for agricultural extension work and this has led to their participation in the Rukwa project.

Over the past four months, under the direction of Dr. B. King of

BRALUP, the Uyole Soil Research Officer, Mr. C. Rombulow-Pearse, and his Tanzanian assistants, Mr. Kamasho and Mr. Ley, have been collecting field data and soil samples in the Rukwa Region. While Mr. Rombulow-Pearse and his assistants were in Dar es Salaam and Mlingano (see below), Aug. 25 - 30, the soils information that had been collected was reviewed. Happily, the data in its present form is up to international standards although it requires supporting laboratory analyses. In these discussions it was decided to classify the soils using the three systems currently being used in Tanzania: the D'Hoore system employed for the Soil Map of Africa; the Soil Taxonomy system of the USDA, often referred to as the 7th Approximation; and the system recently created for the Soil Map of the World by the FAO and UNESCO. Further, it was decided to produce the land suitability interpretations along the lines of the new FAO land suitability framework.

An excellent opportunity to discuss the details of the Rukwa soil survey as well as Tanzanian soil surveys generally was provided by attending the Soils and Fertilizer Use Co-ordinating Committee Meeting, August 29 - 30. This meeting was held at the Mlingano Agricultural Research Institute which is located a few kilometres from Tanga in northeastern Tanzania.

This Committee meets annually to critically review the previous year's and the coming year's research work on soils conducted by Tanzania's agricultural research institutes and various parastatal bodies. It then makes recommendations to the Ministry of Agriculture concerning the types of research that should be supported. Dr. King, Mr. Rombulow-Pearse, and I presented an outline of the Rukwa soils work emphasizing the use of LANDSAT imagery and this was favourably received.

Mlingano is the headquarters of the Tanzanian National Soil Service. At present, the Soil Survey Section, which has been in existence for only a very short time, is headed by an FAO Soils Expert, Mr. E.J. Espinosa. Very useful discussions were held with Mr. Espinosa as well as a Mr. E. DePauw (FAO Associate Soils Expert) on the topics of the FAO soils and land suitability classification systems.

The Mlingano visit also provided the opportunity to arrange for the chemical analysis of some Rukwa soil samples. The work will be done under the direction of Mr. R.G. Menon, FAO Soil Chemist.

Item 8 Remote Sensing Familiarization Workshop

On September 12 a full-day workshop on the characteristics and use of LANDSAT imagery was presented by BRALUP (the agenda and my paper prepared a couple of days before are included in Appendix C). Selected University and Government people were invited in an attempt to interest Tanzanians in the use of satellite/remote sensing imagery.

Although the workshop was relatively well attended, BRALUP was disappointed at the absence of any representation from what might be considered one of the major potential users of the technology, the Ministry of Agriculture.

Item 9 Visit to IDRC Nairobi Office

September 15 - 16 was spent in Nairobi where Mr. Robert LeBlond was briefed on the matters contained in this report. In addition, discussions were held on the planned IDRC LANDSAT meeting to be held in Nairobi in March, 1978.

Item 10 Question Re. Cartography

BRALUP is very concerned about its ability to produce and print the maps that are to be prepared for the LANDSAT project. In the first instance, they do not now employ a cartographer/draftsman. The University of Dar es Salaam has allocated BRALUP such a position and they have been advertising it for several months. BRALUP has received very few applicants and those who have applied have been judged to be incompetent. In the second instance, BRALUP is not confident that even if the cartography/drafting were to be done in Tanzania that the printing of the maps would get completed within a year - certainly not before July, 1978, the concluding date of the LANDSAT project. BRALUP is posing the question "Can this work be done in Canada or elsewhere?".

This question raises a number of possibly conflicting objectives. For BRALUP's part, the most desirable map product would be in a form consisting of one to three colours using screening with a production run of 250 to 350 copies. Less desirable but acceptable would be a map product in black and white using overlays with half-tone screens or patterns (the same number of copies). These relatively sophisticated forms of map seem to be a matter of pride with BRALUP and part of a desire to advertise the capabilities of using LANDSAT imagery within Tanzania. The coloured product can not now be produced in Tanzania given the makeup of the BRALUP technical support staff; the black and white product probably could be done in Tanzania but would take considerable time.

From discussions with Mr. LeBlond, these relatively sophisticated forms of map products are not an IDRC requirement of the LANDSAT Tanzania Project and certainly the number of copies is several times that originally

envisaged by IDRC.

Where does that leave us? While in Tanzania I was asked, and agreed, to determine the feasibility and cost of drafting and printing the maps in Canada with or without the facilities of the Department of Geography at Laurentian University. In the few days since my return to Canada from Tanzania I have initially determined that because of the size, complexity, and number of maps involved, this work cannot be done at Laurentian. Therefore if the work is to be done in Canada it will have to be done, for the most part, commercially. This will probably be expensive. As my October work schedule has already been committed I will be unable to obtain any commercial estimates until the end of November, at the earliest. So, the question about the form and number of copies of the LANDSAT Tanzania map products remains unresolved. I feel that the resolution of the question will require some further discussion between Mr. LeBlond and Dr. Mascarenhas.

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APPENDIX A

IDP 3000

DIGITAL IMAGE PROCESSOR

MODULE DESCRIPTION AND
CONFIGURATOR

Document CE/M/014(1)

October, 1976

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1. INTRODUCTION

This document is intended to be of assistance in the task of selecting an IDP 3000 configuration to meet specific technical requirements and price constraints (when accompanied by a current price list).

A brief description is given of the major characteristics of the overall system.

Each module is then described in detail in terms of the functions which it is able to perform (Section 3).

Section 4 describes three typical configurations. Section 5 shows how to select a configuration, taking account of the interdependence between modules.

Section 6 provides guidance in the use of the current price list to determine price.

2. RECAPITULATION ON NATURE OF OVERALL SYSTEM

This document is not intended to stand on its own. To understand the nature, functions and applications of the range of systems which can be constructed, reference should be made to System Introduction

The system manipulates images, which can come from a wide variety of input sources either live, using TV scanning techniques, or via storage such as computer compatible or other digital tape.

Resulting new images can be made available using a range of permanent copy output devices either directly or via computer compatible tape.

The systems are interactive in concept, much importance being given to the guidance of the operator, who observes raw and processed images using a full-colour broadcast-standard TV monitor of studio quality.

Three sorts of processing are made available.

Alpha-processing - is carried out at TV scan rate and appears to be almost instantaneous to the user. Processing reacts to user commands so quickly that manual optimisation of processes is both practical and ergonomic.

Gamma-processing - is carried out slowly by computer software and its value is its flexibility for experimental purposes, and its potentially higher sophistication.

Beta-processing - is intermediate in speed, using fast hardware to implement tasks too complex, too specialised or too different in concept to be incorporated in the Alpha-processing, but which are unacceptably slow in Gamma-processing.

Beta-processing is also intended to accommodate substantial upgrades as the technology advances, so that the system does not become obsolete.

For details of the actual processes and facilities available, and planned under each heading, see System Introduction.

3. MODULE DESCRIPTION

3.1 System nucleus

IDP 3010: The System Nucleus

3010 comprises the nucleus round which a system can be configured. Figure 1 shows its structure. The nucleus is a working system, except that there is no input facility. It includes racking adequate to house all hardware processing and store options. The nucleus alone is capable of processing a single monochrome input from a TV camera. Full contrast function generation facilities are included viz,

- Contrast stretching
- Tinting
- Contouring

The split screen facilities allow four different processing functions to be implemented simultaneously in different areas of the display. In addition a test image (typically a horizontal or vertical wedge) can be inserted in the display. A fully variable rectangular cursor allows the split screen areas to be defined.

The display comprises a high resolution studio quality colour TV monitor. Interaction takes place via an alpha-numeric visual display unit, special function control panel and a rolling ball for co-ordinate entry.

Great care has been taken to ensure that the system matches the operational working methods of photo interpreters. The system is designed as a desk unit, no more than 80 cms high with a top surface suitable for maps. The colour TV monitor is mounted on a hinged cantilever to allow the maps to slide underneath it. The control panel and rolling ball are provided as a separate unit to be positioned anywhere on the top surface.

3.2 Input/output options

The 3010 alone will accept data for alpha-processing via its standard video interface only (625 line, 50 Hz 2:1 interlace)

The 3010 mini-computer has the potential to accept a wide range of peripherals on its normal computer channels (DMA etc.). In any system with digitally-interfaced peripherals a 3140 and suitable store are essential to link the images to alpha-processing and display.

In connecting a required peripheral the most suitable interface must therefore be chosen -

- analogue video signals to 3010 digital signals
- direct to 3010 minicomputer or
- direct to 3190 minicomputer or
- to Gamma-interface or Beta-interface on 3140

We will be pleased to give advice on, or quote for the connection of any proprietary imaging peripherals such as:

- flying spot scanners
- microdensitometers
- film writers monochrome or colour
- displays
- TV hard copy

Listed below are only the input/output modules specially developed for the system, together with the tape-unit which provides the vital link with all off-line image sources, hard copy facilities etc.

IDP 3020: Optical Input System

3020 is a precision opto-mechanical system which allows the user to input, via a monochrome TV camera, transparencies ranging from 35 mm up to 9" x 9". Roll film of 35 mm, 70 mm and 9" can be accommodated in motorized cassettes. From a field of view incorporating the complete 9" x 9" image the TV camera can zoom in to cover an area 5 mm square anywhere in the image. All movements (x, y and rotation) are motorized and can be stepped at 16 micron or (15 mins. of arc) intervals to allow registration of multi-band transparencies such as those from Landsat. Red, green, blue and clear filters are incorporated to allow the colour components of colour transparencies to be sequentially read and either processed or stored.

The Optical Input System is provided in its own cabinet which matches that of the System Nucleus.

IDP 3030: Basic Camera System

A number of users will find the Optical Input System too sophisticated for their needs. For this reason 3030 has been defined and comprises a vertical camera mount, with baseboard, illuminating lamps and light box. The TV camera is the same model as that in 3020 but all movements and focussing are manual.

IDP 3040: Magnetic Tape Input

The magnetic tape option is supplied together with a disc storage system which is capable of storing a full Landsat image. These standard computer peripherals can be attached directly to 3010 or to 3190.

IDP 3050: Monochrome monitor

It is planned to incorporate a flat face monochrome monitor, independently driven and set into the top surface of the system. This will have variable geometry to allow the image to be matched accurately to a map transparency thus allowing exact locating of identified image features.

3.3 Store options

IDP 3130: Image Store Controller

3130, the basic store controller allows video data from a TV camera to be stored and processed, using up to 16 8-bit stores.

IDP 3150: Channel store - 8 bits

The standard image channel store comprises 512 x 512 picture elements each of 8 bits. Up to 8 such stores can be accommodated physically inside the 3010.

IDP 3160: Channel Store - reduced bits

The Channel Store is a modular system which can accommodate any number of intensity bits from 1 to 8. For those users who do not require the full 8 bit intensity range options 3160 and 3170 are offered. Option 3160 comprises the framework for an individual channel. Note that this does not preclude the need for a 3130, and that the actual bit stores are not included - these are 3170.

IDP 3170: 1 bit Store Module

Up to 8 of these modules can be accommodated within one 3160 thus providing a wide range of quantisation options.

3.4 Alpha-Processing Options

IDP 3070: Vector Unit

Allows the user to combine up to 4 channels arithmetically. A set of three units not only provides the standard additive viewer functions but includes subtractive routines which allow Principal Components images to be constructed. Up to 4 vector units can be incorporated in the 3010 racking. An extremely important aspect of the vector unit concerns the availability of a unique algorithm in the software which guides the operator to the optimum enhancement (or colour combination) for his task.

IDP 3080: Ratio unit

Recent work in the Earth Resource disciplines has shown the importance of ratioing images. This has proved particularly useful in the field of geomorphology. 3080 allows one image to be divided (or multiplied) by another instantaneously, thus facilitating comparison between different ratio'd images. Up to four ratio units can be incorporated in the 3010 racking. If a spare image store is available this option can be used to display an intensity normalised image. Using this approach a wide range of 4 function arithmetic expressions can be implemented.

An automatic scaling facility, 3110 can be associated with the ratio units to optimise the display contrast.

IDP 3090: Simple Fast Classifier

Multispectral classifications, in up to 4 channels, are achieved by logically combining the decisions of eight "cuboid" classifiers each of which slices the intensity in all channels simultaneously. This classifier operates at TV rates and thus optimisation can be undertaken manually. Provided that either 3110 or 3100 is included in the system then software assisted optimisation can be made available.

IDP 3100: Data interrogation

If multivariate image intensity statistics are required it is essential to provide the 3010 with limited access to the image intensity data. 3100 provides such a facility, and is better than a 3140 for this purpose.

IDP 3110: High speed statistics/Autoscale

The autoscale facility discussed under 3080 operates by determining the histogram of a single channel. By undertaking this task in hardware the function can be found in 40 mS thus providing a very high speed statistics facility. From the histogram information, mean, variance, mode, maximum, minimum etc. are available. Thematic area measurement is included.

IDP 3120: Stored image switching

The facility for allowing a stored image to control the split screen display provides a very powerful tool. 3120 allows any stored image, but in particular a computer generated thematic map or cursor generated outline, to control the split screen display. This means that extremely complex split screen arrangements can be defined.

IDP 3200: Stored Image Zoom

Allows manually controlled digital zoom to centre the display at any point in the image and enlarge the image in steps, each step being a factor of two in enlargement. Needs 3140.

IDP 3210: Graphics Display

Generation of line images with the cursor is supported by the 3010 software. This facility is available at no charge provided a 3140 and some store is incorporated, and can include inlay of text.

3.5

Interface options

IDP 3140: Twin BETA-GAMMA interface

This module provides two interfaces.

The gamma-interface links the store to any suitable software processor and is directly compatible with 3190 and with the CPU in the 3010.

The beta-interface is a general-purpose interface intended to provide for substantial enhancements to the system. See section 2 for the nature of the beta-processors which it allows to be connected.

3.6

Gamma-processing options

A CPU to support software image processing can be provided in three different ways, on condition that a 3140 is available as the necessary interface.

GAMMA 1: As an absolutely minimum cost system the Prime 100 CPU in the 3010 can be used. The disadvantages are that all interaction with the display is locked out whilst processing is being undertaken, and that the associated "core" store is rather small.

Some improvements in speed and capacity are achieved by upgrading the 3010 CPU to a Prime 300 and using as above.

GAMMA 2: A superior, and highly recommended, configuration employs a separate Prime 300, leaving the 3010 dedicated to the interaction task. Connects directly to the 3140.

GAMMA 3: For the customer who already has investment in an alternative computer the IDP 3000 can be regarded as a peripheral, connected via the 3140. This will necessitate simple hardware interface and software drivers which are special for each computer, and can be supplied at small extra cost.

The hardware to support GAMMA 1 is not a separate module, all that is required is a 3140 and some storage facilities.

The relevant modules are:

IDP 3180: Nucleus CPU Upgrade

This upgrades the Prime 100 computer in the 3010 to a Prime 300. Its purpose is to improve the viability of GAMMA 1 processing as described above.

IDP 3190: Main Gamma-Processor

A main computer to carry out software image processing. Consists of a Prime 300 fully interfaced in hardware and software to the rest of the system, which must include a 3140. It has the advantages as follows over the GAMMA 1 approach

- (a) allows image display and interaction, including alpha and beta processing, to continue undisturbed whilst slower and more sophisticated image processes are being undertaken.
- (b) software processing can be operated in time-sharing mode, allowing several users simultaneous access to the data if a few more terminals are added.
- (c) can drive more than one IDP 3000 system simultaneously
- (d) more room for larger software packages.

The ease of connection of the system to other computers (GAMMA 3 above) has been considered to be an important design feature. Hardware and software interfaces have been kept as simple and general purpose as possible. Advice and quotations for connection to any other machine will be given on request.

3.7

Beta-processing options

As described above, the beta-processing interface is provided by 3140. It is intended to accommodate advanced or special purpose processors, intermediate in speed between the software gamma processing and the TV rate alpha-processing. It is planned that substantial system upgrades should take place via this interface. Detailed below are the modules which are under development, although no prices are available at the date of this document.

IDP 3220: Spatial Filtering Processor

This module will filter a single channel spatially, using direct convolution with a 16 x 16 window set by 3010 or 3190. Multiple passes can filter multiband images. This filtering makes it possible to emphasize or de-emphasize high frequencies, low frequencies or edges to remove noise with particular spatial frequency characteristics, and to achieve many other well known effects for image improvement. In particular, a set of textual features can be built up in store and then used for classification.

IDP 3230: Fast n-space Classifier

Under the control of a software driver, this module implements a general purpose n-space classification in accordance with a decision algorithm which has been optimised for a given task. The optimisation is the responsibility of software.

IDP 3240: Spatial Feature Extractor

A module incorporating aspects of 3220 processing in a more sophisticated framework so that selection of filters for a classification task becomes invisible to the user, who simply specifies training areas and then assesses and corrects the classification designed and implemented by the machine.

Further modules are planned as part of a continuous programme of capability enhancement. These include for instance spatial interpolation, to speed up the geometric rectification of images which is otherwise a lengthy software process; and facilities for using multi-temporal image sequences in a more sophisticated way than their straightforward use as multiple channels (which is simple with existing modules).

4.

TYPICAL CONFIGURATIONS

Figures 2, 3 and 4 show three typical configurations of the IDP 3000 System in ascending order of complexity.

Configuration TC 1 is a stand-alone system for undertaking alpha-processing on images in transparency form. Five channels of store (3150) have been incorporated; these would typically be assigned to 4 multi spectral components and a processed image although these assignments are made by the operator and are fully flexible. Operationally the image store would be loaded from 3020 either with separate monochrome images or the colour components from a transparency. Four ratio units, 3080, have been included to allow simultaneous ratioing of the stored images and subsequent recombination in the vector units (3070). Module 3090 allows the data to be classified. The displayed data can thus comprise any linear combination of images, both ratio'd and original, and either classified or unclassified, contrast stretched or density sliced. The split screen facility makes four such combinations available simultaneously in different areas of the screen. Any image can be restored although in TC 1 this would be limited to one monochrome if the input comprised a 4-band transparency set, and 2 monochromes if it were a normal colour transparency. Any stored image can be used to control the split screen, using module 3120, and thus a classified image or a stored cursor locus can be used to mask out areas for subsequent re-classification. In this way a very complex classification system can be constructed.

Image quantification is provided by modules 3100 and 3110. The autoscale and histogramming facility is used to provide area measurement figures as well as standard statistical data. Detailed colour co-ordinate data can be obtained using the data interrogation facility.

Configuration TC 2 includes the upgrade of the 3010 to a Prime 300 processor with additional memory, the provision of magnetic tape and disc backing store and the addition of the processing interface 3140. Note that 3130 is still required although it does not appear on the diagram. This system supports beta and gamma-processing and has the same alpha-processing configuration as TC 1.

Configuration TC 3 is the recommended implementation for gamma-processing functions. The Prime 300 is a separate machine which can be operated in a time-sharing mode thus allowing several users access to the data for program development. Note that the additional terminals and peripherals are not covered in the price quoted for 3190. An upgrade from TC 2 to TC 3 is straightforward..

5. SELECTING A CONFIGURATION

The first step is to decide from Section 3 which modules are functionally essential for the requirement under consideration.

It is then only necessary to identify any additional modules which the system needs for viability, in terms of controllers and other support.

Figure 5 provides a simple diagrammatic method of identifying these support modules.

To use Figure 5 act as follows:-

- (a) Mark desired modules in pencil
- (b) Draw a single pencil line to pass through all desired modules in direction of arrow, and complete an unbroken circuit round the central point of the diagram.

This forces the line to pass through any additional modules which may be needed. Note all modules through which the line passes. These will make up a viable system.

6. GUIDANCE ON ESTIMATING PRICE OF A CONFIGURATION

IDP 3000 price lists are available, covering major geographical areas of the world. Differences arise primarily from wide discrepancies in the cost of servicing the warranty at different locations.

Using the current price list for the applicable geographic area, price can be estimated by simply adding the prices of the modules identified in Section 5.

All price lists which refer to this document are valid under the following conditions:-

- (a) The prices quoted for individual modules only apply to purchasers of the System Nucleus IDP 3010. However all modules may be purchased individually without the Systems Nucleus and prices are available on request.
- (b) All prices are quoted F.O.B. U.K. airport or port.
- (c) All prices are exclusive of installation and commissioning charges which will be quoted separately for customer specified locations.
- (d) The prices quoted include System Warranty for one-year following System handover. Full maintenance support is available and will be tailored to meet specific customer requirements.

- (e) The prices quoted include initial training for one operator in the U.K., exclusive of travel and subsistence. Comprehensive Operator and Maintenance training courses are available and these would be tailored to meet individual customer requirements.
- (f) The prices quoted are exclusive of any import dues and taxes which may be levied.
- (g) The prices quoted are inclusive of Basic Operating Software, including all necessary software drivers, and the complete alpha-processing system software. Gamma processing systems will be tailored to individual requirements, for which a nominal charge may be made.
- (h) The prices quoted are subject to agreement on terms and conditions of contract.

7.

SOURCES OF FURTHER INFORMATION

Further information is available as follows:-

Technical: Mr. O. E. Morgan,
Remote Sensing and Image Analysis Unit,
Plessey Radar Research Centre,
Southleigh Park House,
Eastleigh Road,
Havant,
HAMPSHIRE,
United Kingdom

Telephone (070 12) 6391 Extension 519

Contractual
and Price:

Mr. B. Stollard,
Plessey Radar,
Station Road,
Addlestone,
Weybridge,
SURREY,
United Kingdom.

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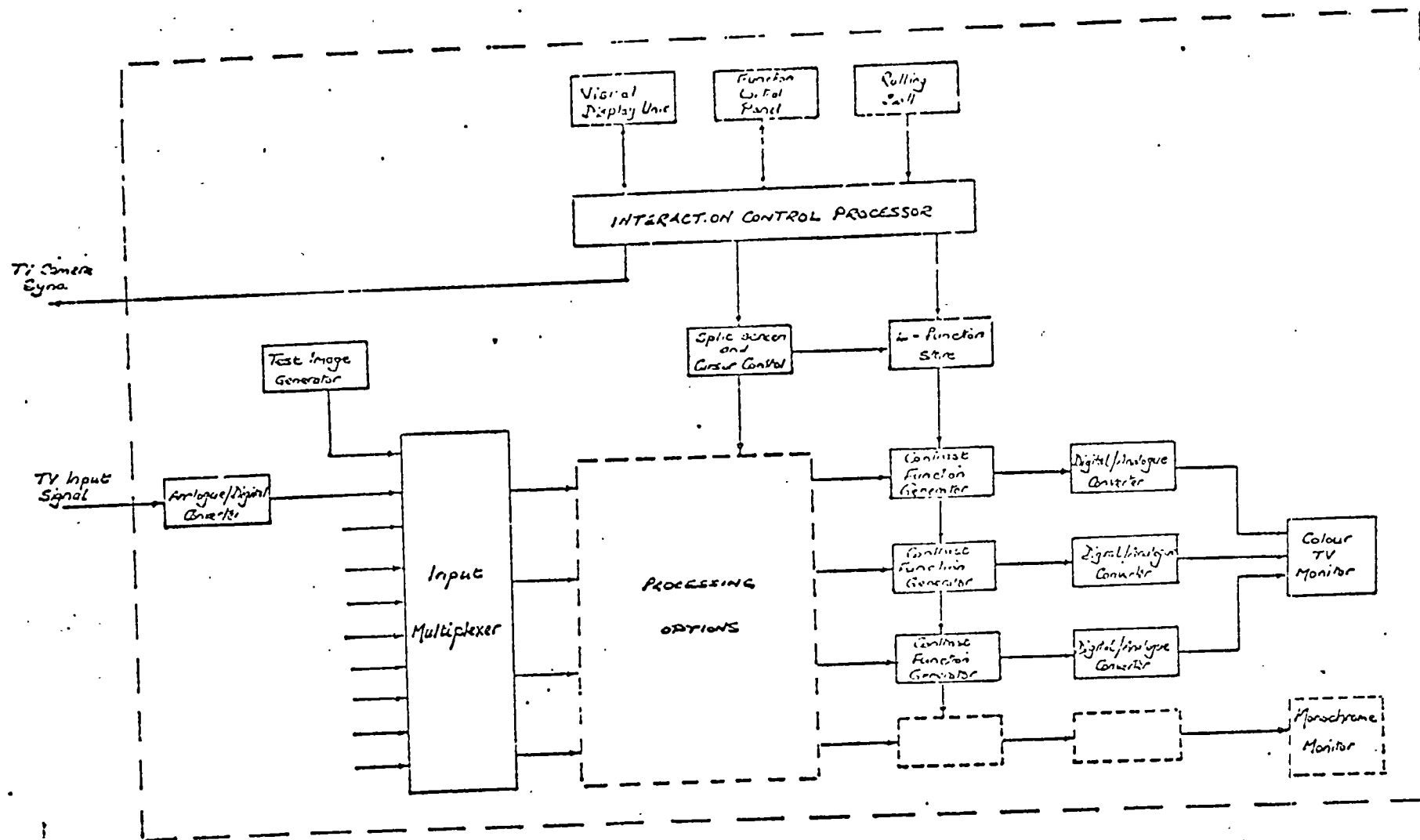


FIG. 1 IDP 3010 : THE BASIC SYSTEM

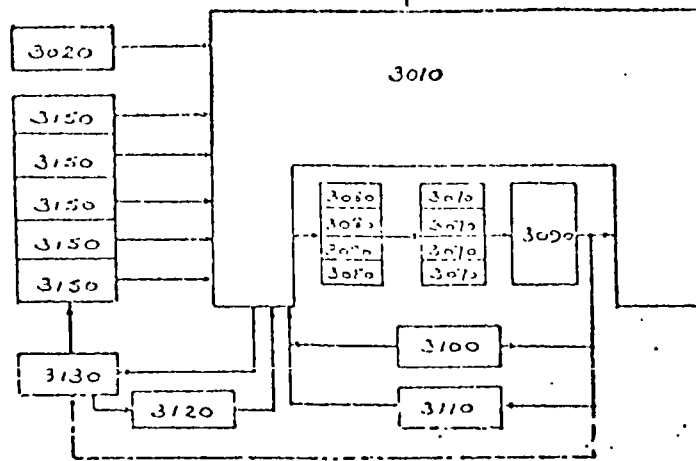


FIGURE 2 - TYPICAL CONFIGURATION 1

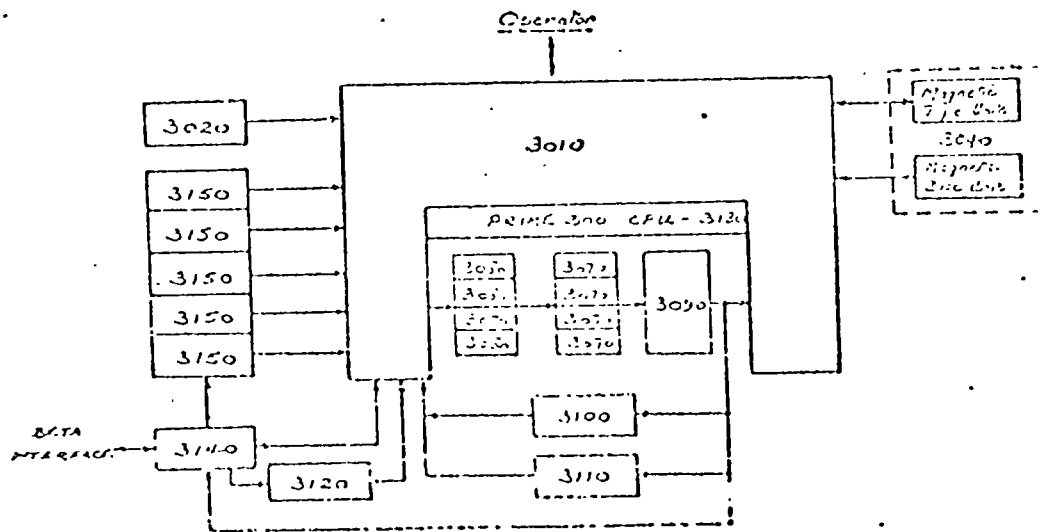
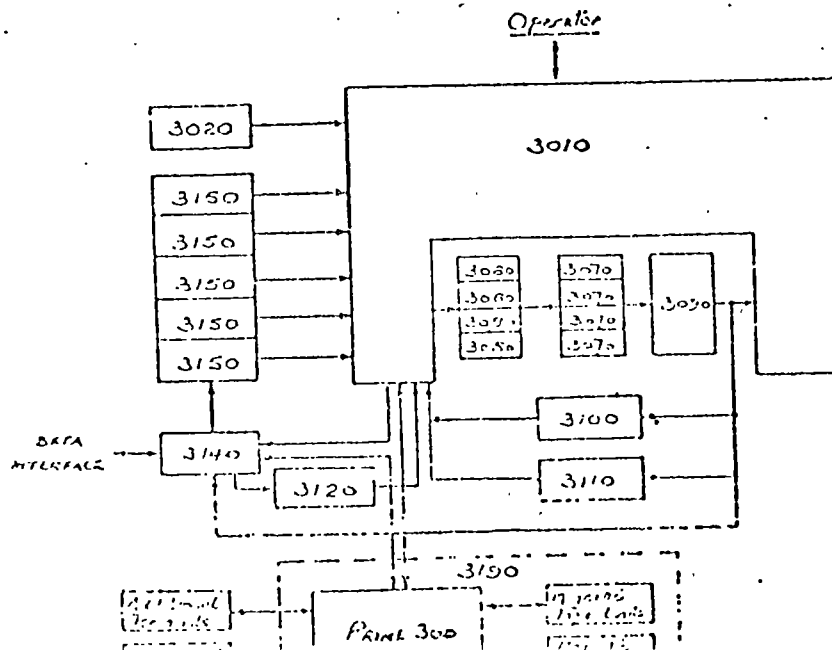
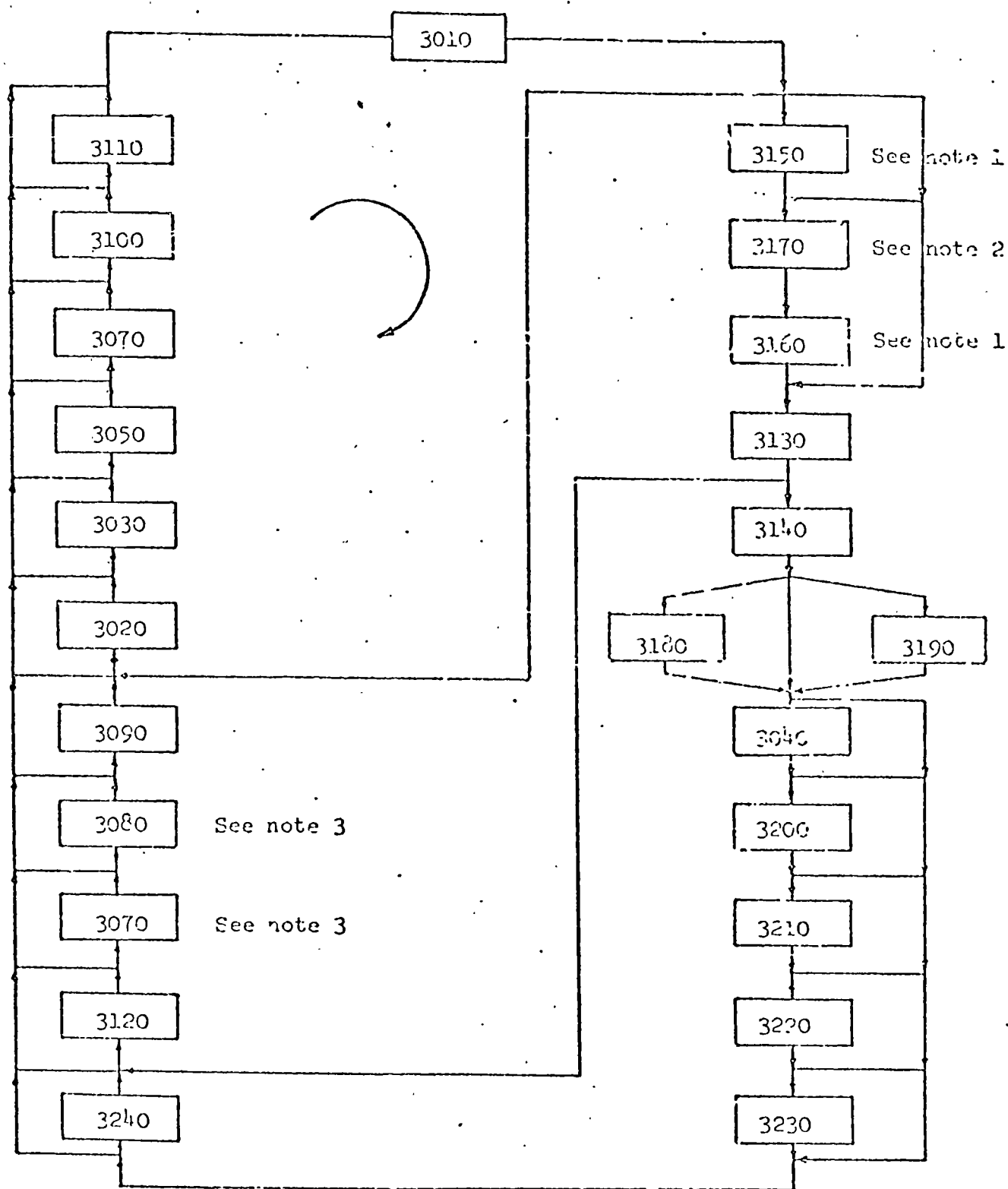


FIGURE 3 - TYPICAL CONFIGURATION 2





1. Each 3130 can control an unlimited number of 3150's and 3160's although the 3010 system nucleus is wired for a total of 8.
2. Each 3160 can control an image store of up to 8 bits resolution. Special systems can be quoted if more than 8 bits are required.
3. The 3010 can accommodate up to 4 3070's and 4 3030's.

DATA REDUCTION AND INFORMATION EXTRACTION FOR REMOTELY SENSED IMAGES

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Brief discussion of the particular problem of image processing leads to a description of the author's computer system for the interactive design and optimisation of such processes and also of the sensor package characteristics required for particular purposes. The relevance of this latter optimisation to the Spacelab mission concept is pointed out and the author's proposals in this direction sketched. Examples are given from the author's research computer facility, of which a brief description is made of the modular image processor which his Company is soon to market.

1. INTRODUCTION AND RATIONALE

ESA HAS EXPRESSED the view [1] that U.S. emphasis on data acquisition has outstripped capabilities for processing and interpretation, producing a "processing gap", and emphasises the importance of ensuring that future work is adequately balanced in this respect.

ESA also considers [2] that Spacelab's optimum role in Earth observation missions will be to allow development of sensors and methods which might then allow direct specification of optimum operational unmanned satellite systems, avoiding intermediate unmanned experiments.

The work reported in this paper seeks to alleviate the "processing gap" by the use of rapid computer assisted design-of-processing algorithms and of sensor selection and optimisation. The approach requires the use of a first stage of data gathering characterised by high resolution and "broad spectrum" measurements, high data quantities, and flexible and intelligent control. The data is then used for the design of optimum fixed or switched sensor packages and out-station processing packages which allow operational data acquisition to be autonomous and minimum cost. This first data gathering stage fits exactly with Spacelab mission characteristics. Thus the approach lines up well with the ESA view in tackling an area of importance and in making precisely the right sort of demands on Spacelab.

2. IMAGE DATA — ITS NATURE, HANDLING AND COMPRESSION

2.1 Background — Data in General

From a source of sensed data to a derived decision or action, data reduction is invariably involved. The demand for data reduction may be due to channel (and store) limitations, or it may be due to the need to strip away the irrelevant, which in the limit results in "decisions".

In a system where sensor is remote from user, and channel costs are high, the optimisation of the chain of sensors, channels, and processes is a particularly acute problem. Sensing from satellite platforms has this characteristic.

Channel capacity problems can be alleviated without losing anything if the data has suitable structure. By this we mean that if not all sub-items of data are equally likely to occur then we can code up the data so that probable items are efficiently coded while improbable ones take a long time. In the limit we may deliberately destroy the channel's capacity to convey data items we know will never occur, in order that we may share out that saved capacity amongst those we know will occur often. Coding theory gives qualitative and quantitative results on how much reduction can be achieved.

irretrievable loss of some of the data. This can only be acceptable if the lost data is unwanted, and thus such a reduction algorithm is only valuable relative to the purpose to which the data will be put. The more limited and well defined the purpose is, the more readily and safely the data can be further reduced.

Thus knowledge of (and use of) structure which may exist in the data allows the data to be reduced without loss of information (i.e. the original data can be largely reconstituted after passing through the channel). This is "data compression". Data can only be further reduced in safety through an understanding of the purpose for which it will be used, by discarding that which is irrelevant. This is "information extraction".

2.2 Relation to Image Data

The background discussion above was applicable to data of any type. We have seen that data compression relies on the discovery and use of structure in the data. Information extraction also relies upon such structure, and also upon an understanding of the task itself.

Structure can be regarded as the existence of relationship between parts.

In the case of a signal the data has a fundamental "adjacency" structure which is one dimensional. Data points or samples occur in a definite time sequence and two points may be near or far apart. Statistical structure which may be of use then exists in relation to this structure. For example a bandwidth limitation expresses itself as a constraint on the intensity difference between points, dependent upon their distance apart.

The data with which we are concerned has other adjacency relationships. In an image there exist the two dimensions of the plane of measurement. In general, however, there may also exist:

- (a) A third dimension associated with multiple sensors which have been simultaneously deployed, e.g. a 13-channel scanner produces 13 simultaneous images which can be regarded as making up a three-dimensional block of data.
- (b) A fourth dimension associated with gross observation time. This is applicable where change information is relevant.

Thus the data with which we are concerned can be regarded as four dimensional. The first, second, and fourth dimensions are the most valid from this viewpoint, in that they each possess intrinsic continuity (i.e. space-time). The

system where observations are in spectral order, but must be regarded as discrete where widely different sensors are used.

Thus, each data point exists in the context of a four dimensional locale. For data compression it may not be cost effective to find and use structure as complicated as this. Indeed, the time dimension will not be readily available in most cases. Data compression factors well below that which could be achieved may therefore be used, capitalising only on spatial structure, or perhaps even on merely the one dimensional structure of an image scan.

For information extraction, however, such a simplified treatment may not be possible. Decisions and conclusions may be required which cannot be reliably achieved without taking into account significant structure in a four dimensional time-space-sensor locale of the region of interest.

This poses very significant problems.

2.3 Data Handling

Not least of the problems is that of handling the data so as to allow rapid retrieval of the four dimensional blocks of data associated with such a locale. In a machine with a sequential one dimensional store, an eight-point-square locale will involve assembling 512 sections of data taken from widely different parts of the store. Substantial high speed random access stores are needed. This speed problem is not trivial even where a single image is involved (i.e. no time or multi-sensor data) if the image is large.

2.4 Information Extraction

The main problem, however, lies in the discovery of the structure which carries information relevant to the required task, which, in essence, is the problem of designing information extraction algorithms for specific tasks, on the basis of analysing representative data of the type discussed above.

3. STATE-OF-THE-ART

3.1 The Requirement

Extraction of information from images operationally is still largely carried out manually, typically by highly skilled interpreters, [3, 4] but this situation must change, at least for the more mundane extraction tasks, due to the following reasons.

- (a) Advances with platforms and sensors have made it possible to gather very large quantities of novel imagery rapidly.
- (b) The novel qualities of these images offer users a potential which they wish to grasp.
- (c) The above two combine to provide a large excess of images obtainable and usable above that which can be manually interpreted, due to shortage of interpreters and to cost.
- (d) Many of the image data interpretation tasks now seeking solution are ill fitted to direct manual methods due either to multi-band or multiple sensor nature (which cannot be displayed), or to use of sensors providing data which fits ill to the intuition of interpreters (SLAR), or to excessive important of time information or other information difficult of human interpretation.

Thus we see that even neglecting the "quantity" argument, machine (or machine assisted) interpretation is to be of major importance.

3.2 The Straight-Forward Approach

The bulk of the relevant work in the open literature has been concerned with "multispectral classification". Such work typically excludes temporal information altogether, and works on data which consists of sets of simultaneous images obtained in different spectral bands [5, 6].

The locale of a data point is thus three dimensional (i.e. as described in 2.2 but with no multiple times). It is significant, however, that typical work has reached decisions on a classification for each point in the image without even taking account of the full three dimensional structure around it, but using only the single dimension represented by the multiband samples. Such a classification is described as a spectral classification; it ignores the spatial information which is available in the data set. Such a process is completely blind to texture, pattern, shape, grain, lineamentation, etc. The addition of post decision smoothing is sometimes seen, and this does use a one or two dimensional locale, but fails to alter the inadequacies noted above.

Work with spectral classifiers rapidly showed that there was a requirement for frequent design of new processing algorithms, and continual redesign of existing ones. This requirement arose from realisation that:

- (a) Even for a fixed interpretation task, a fixed algorithm is not possible, due to substantial data variability arising from atmosphere, illumination angle and numerous other factors which mediate against the concept of an ideal spectral signature.
- (b) Due to equipment cost and wide variety of different tasks, it is likely that an equipment will need to service many different problems, so that algorithm design occupies much time.

This requirement for continual redesign underlined the need to deduce the required processing by rapid analysis of representative data of known class, preferably taken from amongst the current data set and therefore embodying the same values of the variable factors mentioned in (a).

Techniques and systems of this type fall within the field of "pattern recognition" which has a well developed technology and literature of its own, not necessarily related to image data only but rather to automatic and semi automatic design of decision algorithms *via* analysis of representative data [7, 8 and 9].

The need for on-line design of the decision algorithm, and for its guidance, implies that the system is based around man-machine interaction.

3.3 Systems Being Marketed

Several systems of this type are now on the market. In these systems the facilities for redesigning and adjusting the decision algorithms are semi-manual, and the systems can be, and are being, used equally well for manually controlled image colour enhancement in which the final conclusions still arise from manual inspection.

It should be noted that, although these products do allow adjustment of the decision algorithm, they do not (except by simple switch selection) give any significant support to the on-line design of processes for reducing the input data prior to the decision process. This is because such steps are unnecessary where the data is already in a suitable reduced form for direct handling by the decision algorithm or classifier. Since no spatial information is used in the equipment under discussion, this is the case. In fact, it could be said that it is in order that this shall be the case that all spatial data is excluded. To use pattern recognition terminology - these systems incorporate "classifier training" - they do not incorporate "feature selection" because

their features are fixed as the spectral bands.

3.4 More Advanced Work

Apart from these spectral-only products there are a number of R & D facilities in existence where the use of spatial data is being explored.

There is in this case, a need for a drastic data reduction step before the standard decision algorithms ("classifiers") of pattern recognition can be brought to bear. This data reduction must operate on at least the two dimensional locale of the point of interest in the picture plane. In multi-sensor and multitemporal situations a full four dimensional locale may need to be handled. This data reduction must in general be well matched to the purpose to which the data will be put.

This processing stage is known in pattern recognition terminology as "feature extraction" and the process of selecting the relevant measure or "features" is called "feature selection".

Thus, the technical problem to be tackled in progressing beyond the limitations of spectral-only classifiers, can be succinctly described as that of spectral, spatial and temporal feature selection.

Work to date in this area can be divided into two categories.

- (a) That aimed at devising specific features of use for one task or class of tasks.
- (b) That aimed at providing general facilities and techniques to support the design of spectral, spatial and temporal features.

Work in category (a) is fairly widespread [10, 11, 12 and 13]. Work in category (b) is fairly sparse [14, 15].

As in the case of spectral-only classifiers, advanced systems require on-line facilities for rapid redesign, category (b) work is of prime importance.

This is obvious where a system provides a multi-user service and therefore, deals with large numbers of different tasks. The use of spatial features should drastically reduce data variability, since atmospheric factors will have much less effect. Despite this, we believe that almost all users will require a flexible redesign capability. This accords with the conclusions of Hornung [16].

4. THE DATA STRUCTURE LABORATORY

4.1 Pattern Recognition and Classifiers

The Plessey Radar team began work in general pattern recognition about eight years ago. Until about three years ago this work was relatively conventional, involving the development of software n-space classifiers together with training software.

The main characteristics of the work were:

- (a) The use of n-space classifiers.
- (b) The use of supervised training. This means that the automatic design of the decision parameters is guided by the analysis of representative data of known class. This is in contrast to unsupervised training in which natural data clusterings are found regardless of their relevance to the task in hand.
- (c) The avoidance of any assumptions about the shape of the class distributions. This means the use of non parametric methods, rather than estimating (for instance) best-fit gaussian distributions. Thus maximum likelihood methods are not used.

- (d) Concentration on decision algorithms rapidly and economically implementable in software and hardware.

Because we always have a known purpose in classifying data, (b) was chosen. The choice of (d) is natural in a practical non-academic environment, whilst (c) results partly from the desire not to mishandle non-gaussian classes and partly from (d) (i.e. to avoid complex algorithms). Thus we consider it worth trading increased design effort for decreased run-time complexity [17].

In addition to the software (which resulted in a software suite named PRS516) a modular hardware classifier was developed known as FTC1 (Fast Trainable Classifier 1). This equipment is analogue, parallel, and has a classification time of less than 1 μ S. The model constructed could deal with 10 output variables and eight classes. Training is by plug in resistor boards specified by the training software.

In the last two years both FTC1 and the PRS516 algorithms have been applied to spectral classification of remotely sensed multiband images. Performance and capabilities in this mode are commensurate with those widely reported by other workers and will not be further discussed [18].

4.2 Feature Selection

For the last three years we have been concentrating on the feature selection problem. This was originally conceived as the problem of designing the sensing or processing to reduce the input data to a few variables (or features) suitable for input to an n-space classifier (usually not more than 20-30).

An interactive computing system, the Data Structure Laboratory, has been produced to support the feature selection task. The major part of its facilities are implemented and running. The Data Structure Laboratory is now a tool for the interactive, semi-automatic design of whole or part of an information extraction system of the type described, including optimisation of sensor packages. It depends on the examination and analysis of representative data.

4.3 Form of the Data Structure Laboratory

The overall form of the Data Structure Laboratory is shown in Fig. 1. The interfaces A, B, C, D and E with the operator use a visual display. Arrows showing the operator's control actions are omitted for clarity.

Tables 1 and 2 give an impression of the software capability as it existed in June 1975 with respect to the library transforms available for signals (1 dimensional) and images (2 dimensional).

In order to communicate something of the style and the capability of DSL, we present a number of figures which are photographs of the VDU outputs, and in the next section we describe a particular problem in the design of an image sensor package which was tackled with its assistance.

Figure 2 shows some typical raw data displays appearing at interface A in Fig. 1. An important aspect is that of selecting and retrieving data from the bank, so that the data from adjacent space, time and (for instance) spectral band can be brought together.

Figure 3 shows some typical displays of data which have been transformed by the system as a result of the operator interaction. These represent interface B.

Figure 4 shows typical cluster plots from interface C. These are shown either as perspective views of histograms or as 2-dimensional cluster plots with data point density displayed as a scaled 0-9 integer.

It should be noted that, in general, the data has many more than two-dimensions, so a viewpoint has to be selected. Viewpoint selection can be manual, or the two axis direction can be selected by the system.

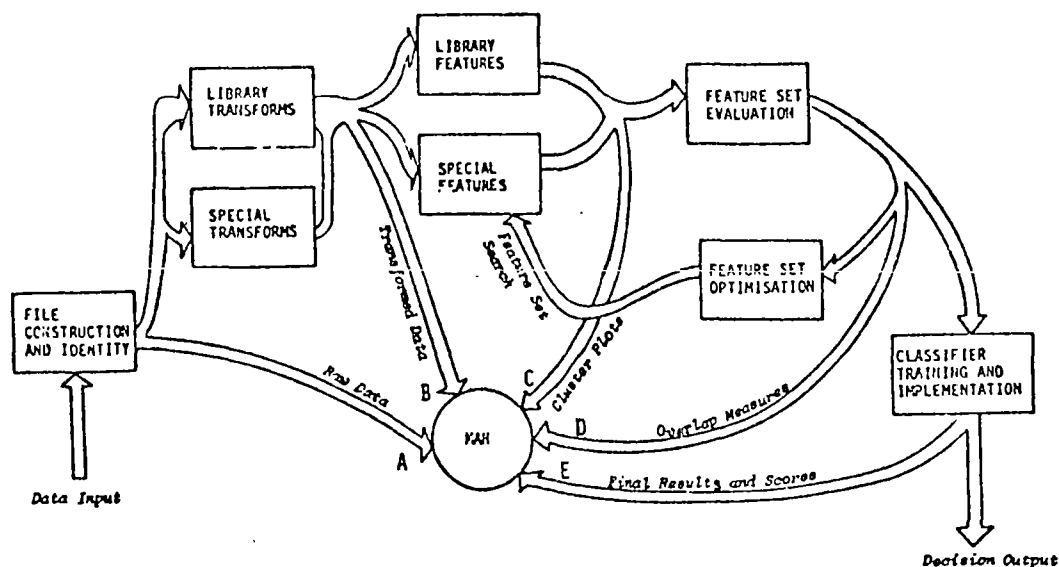


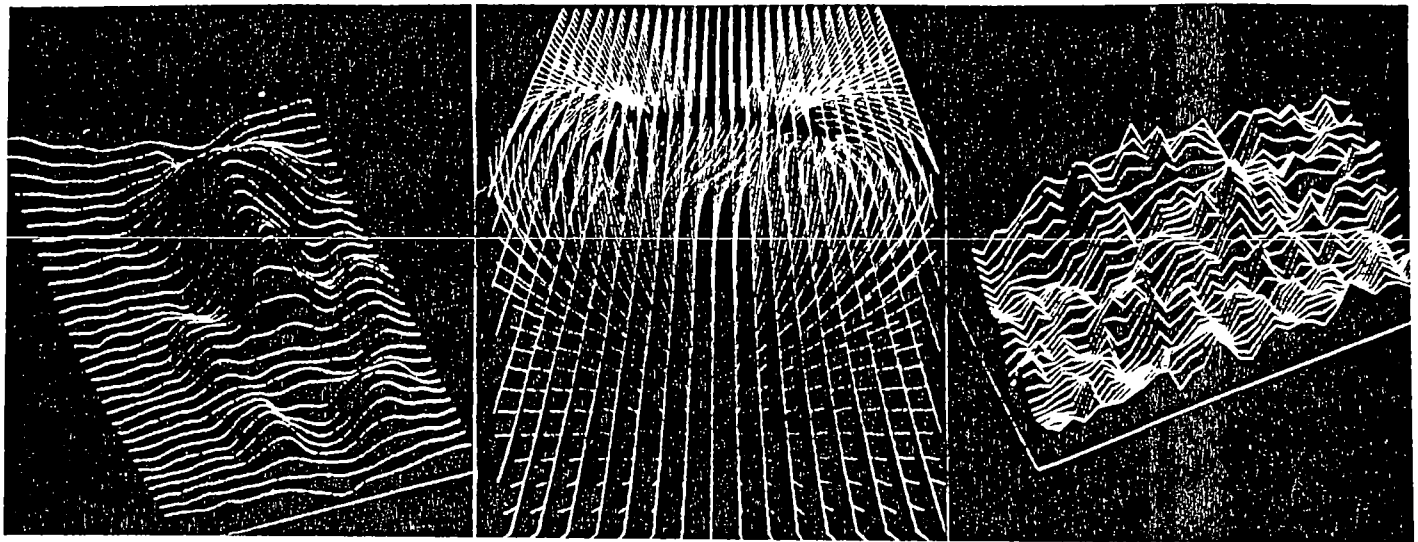
Fig. 1. Data Structure Laboratory.

TABLE 1. DSL signal transforms (June 1975).

Linear Transformation	Manipulation
FOURIE (Fast Fourier Transform)	SHIFT (Circular Shift)
SPFFP (Fourier Power Spectrum)	SPCON (Circular Convolution)
FFTPA (FFT, Phase, Amplitude)	CRCOR (Auto-Correlation)
SPHAD (Hadamard Power Spectrum)	SPCOR (Cross-Correlation)
SPSIM (Simplex Transform)	SPMULT (Vector Product)
HADPW (Hadamard Power Spectrum)	SPADD (Vector Addition)
	SPHAS (Phase of the Power Spectrum)
	POWER (Amplitude of the Power Spectrum)
	SPAMPS (Square Amp or Root Power)
	PHAMP (Phase and Amplitude of Power Spectrum)
Enhancement	Recursive Filters
SPLOG (Log ₁₀)	LPASS (Two-Pole Butterworth -- Low Pass)
REMDC (Remove D/C Term)	HPASS (Two-Pole Butterworth -- High Pass)
SPTHR (Threshold)	SPBST (Two-Pole Butterworth -- Band Stop)
SPSQR (Hard Limit)	BPASS (Two-Pole Butterworth -- Band Pass)
SPRTS (Inverse Time Sequence)	SPCLP (Four-Pole Chebycheff Low Pass)
SPDIF (Differentiate)	
SPINT (Integrate)	
TREND (Remove Trend)	

TABLE 2. DSL image transforms (June 1975).

Enhancement	Windowing	Transform Domain Filters
RMV (Remove Minimum Value)	SMH (3 x 3 Smoothing)	FTTFL (FTT Domain in Band Pass)
AMV (Add Input Value)	LAP (3 x 3 Laplacian)	I LORM (FFT Domain Ormsby Filter Low or High Pass)
TRP (Transpose)	SLS (5 x 5 Smooth Laplacian)	HADFL (Hadamard Domain Band Pass)
ATP (Transpose about other Diagonal)	SL7 (7 x 7 Smooth Laplacian)	SNTFL (Slant Domain Band Pass)
ISP (Interchange Scan Positions)		SNTTD (Trend Removal Special High Pass SNT Filter)
RSD (Reverse Scan Directions)		FTTAF (Alpha Filtering)
INV (Invert Data)		
NOR (Normalise about Mean)		
EXP (Exponentiate)		
NL Transform	Linear Transformation	NL Enhancement
NLE (Non-Linear Edge Detection)	FTTSG (2-D FFT Forward)	TRH (Threshold)
NLS (Enlarged Version)	FTTIV (2-D FFT Inverse)	LIM (Hard Limit)
DTL (Spot Detector)	HADSG (2-D Hadamard Transform)	LOG (Take Natural Logarithm)
	HADIV (2-D Hadamard Transform)	SQR (Square Amplitude)
	SNTSG (2-D Slant Transform)	SQT (Square Root)
	SNTIV (2-D Slant Transform)	HIT (Threshold Digitiser)
		SNL (Raise to a Power)
		BSN (Bit Clipping)
		TRD (Trend Removal)
Recursive Filters		
BPS (Butterworth Band Pass along Scans)		
R2D (Butterworth Band Pass Symmetric 2-D)		
CL1 (Chebycheff Low Pass Symmetric 2-D E = 0.1)		
CL9 (Chebycheff Low Pass Symmetric 2-D E = 0.9)		

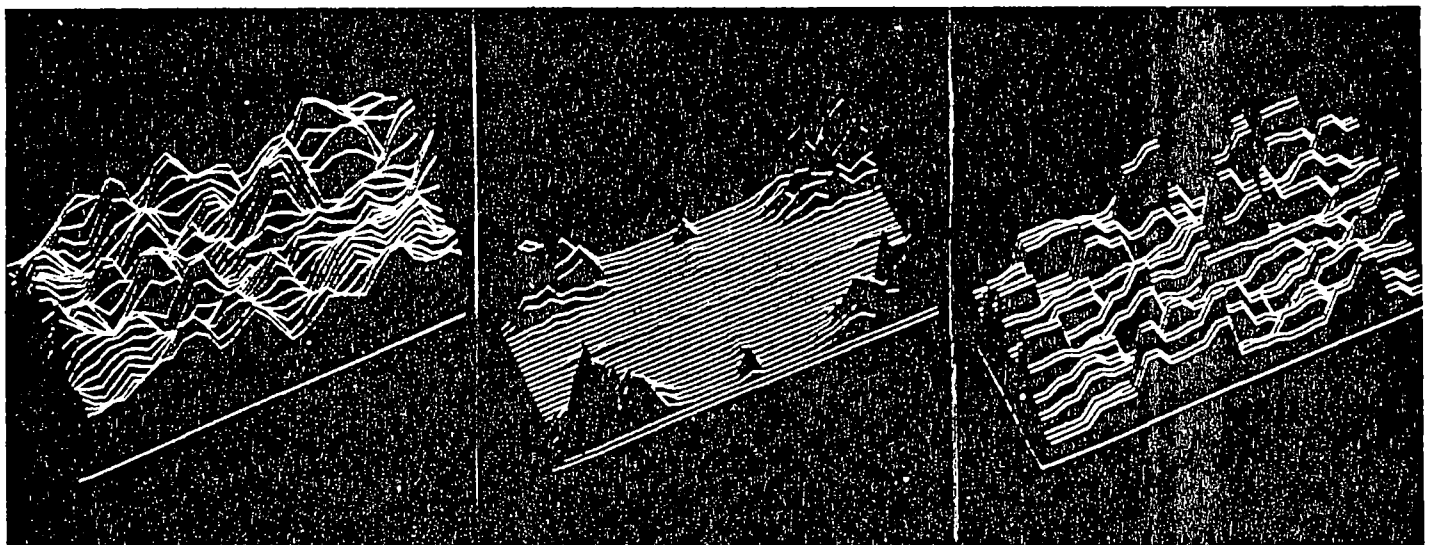


Human Torso, Microwave Radiometry

Three Band Image, Magnetometers

Miscellaneous, Data Window A

Fig. 2. Raw data displays for image windows.

Window A
Low Pass Filtered in Power Spectral Domain

Power Spectrum of Data as at left

Window A
Low Pass Filtered in Hadamard Sequence Domain

Fig. 3. Examples of spatial transformations.

may use the eigenvectors of the covariance matrix (i.e. Principal Components Analysis) where it is desired to treat the data as a single class, or may use discriminant analysis on selected class pairs (two pairs per display) where class distinctions are being examined, see Ref. 19.

Data can also be displayed as a two-dimensional plot in which interpoint distances have as far as possible been preserved. Such a transformation is not in general quickly implementable at run-time since it is non-linear with no economic generation algorithm, [20]

We have tried a number of three-dimensional cluster displays (including the use of stereo vision) but have not found them practically useful.

4.4 Use of DSL for Feature Selection

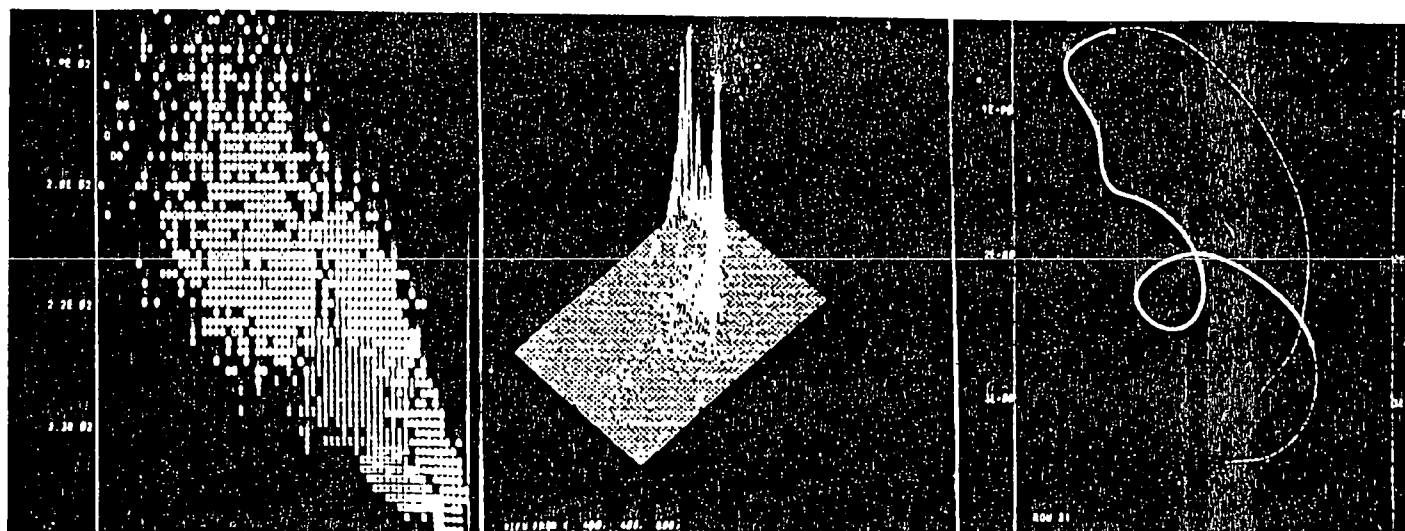
The operation of the "Feature Set Optimisation" package in Fig. 1 is represented by a pair of cluster plots in Fig. 4.

turned out to be much simpler than expected, with the two best features highly correlated, and a simple threshold adequate for the decision.

The use of the system for feature selection, *via* computer optimisation, requires, in principle,

- An evaluation function to allow performance of feature sets to be compared.
- A parametrised universe of feature sets to be searched through.
- Search algorithms capable of using (a) and (b) to achieve such search economies as may be necessary.

Unfortunately things are not quite this simple. The selection process breaks naturally into a two level hierarchy. The first stage is the finding of potentially good individual

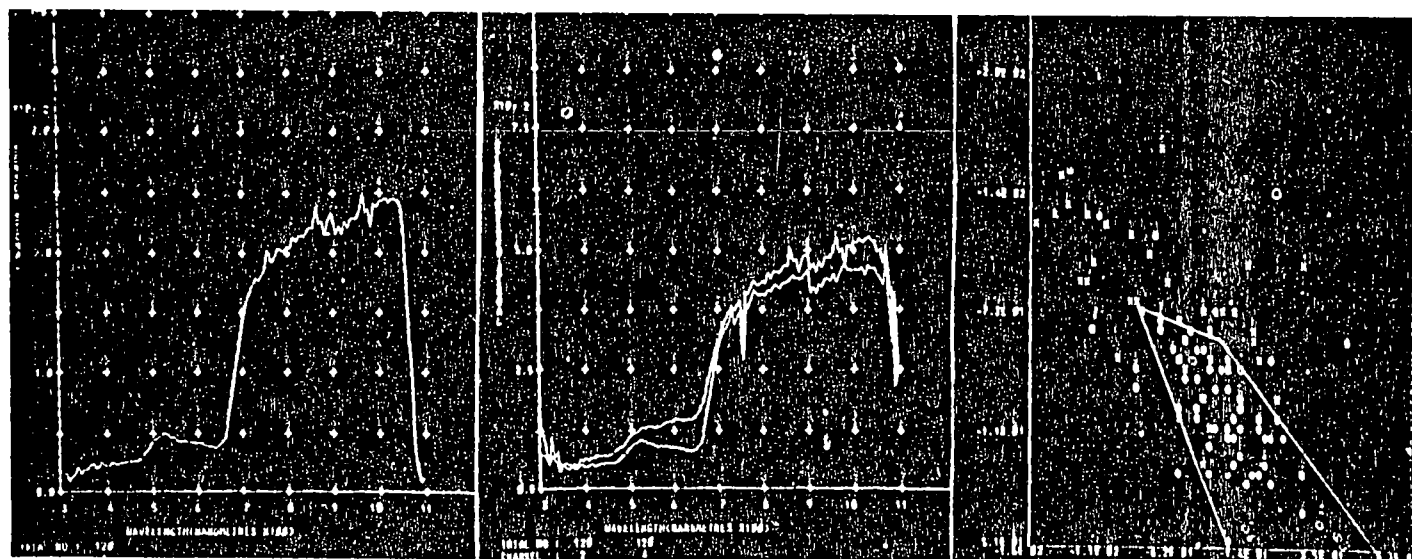


Six-Class Discriminant Plot Multi-band Photography

Single Class Histogram Multi-band Photography

Temporal Movement Spline Interpolated

Fig. 4. Views of cluster plots etc. in n-space.



Raw Data Spectrum

Normalised for Incident Radiation

Fig. 5. Vegetation reflectance spectra.

Fig. 6. Two-class cluster plot for data at left.

which perform well together.

The second stage is itself further complicated by the requirement, simultaneously, to maximise the group performance of the feature set and to minimise the similarity between its features to prevent wasteful duplication. The division between the two levels of the hierarchy, although very useful, is not (of course) absolute, and feedback between the two can be considered as a further sophistication.

After much experimentation and comparison, we now tend to use as our principal evaluation measure to determine "cluster overlap" the Fix and Hodges Test [21] or close derivations thereof. This measure has the advantage of being distribution-free.

We have implemented and evaluated a number of two-stage procedures. A typical procedure involved single feature selection by hill-climbing optimisation from a random high-scoring starting position, followed by feature set selection using a sequential procedure which adds at

each stage the feature having maximum score from amongst those falling below a threshold of similarity with those already chosen [22]. The Weighted Sum Evaluation Procedure [23] is similar to these second stage techniques and has also been implemented in DSL.

All such sequential methods suffer inadequacy resulting from high dependence on early feature choices. We are developing improved methods overcoming this difficulty by throwing out features later found to be non-contributing.

4.5 Conclusions

The DSL, in its full generality, is equally applicable to a variety of data types, and to the design of sophisticated processing or the simple selection between alternate sensors or sensing bands. A considerable proportion of current work is concentrating on the design of spatial processing optimally matched to the task in hand. The basic concept is

highly interactive, and even the optimisation loops may be monitored and guided by the man when desired.

In practice, two operators work with the machine. One is from the application team and brings detailed understanding of the data and the task. The other is a data structure expert and brings understanding of essential clues to relevant structure, and of how to use the system capabilities to the full.

5. USE FOR DESIGN OF SENSOR PACKAGES

It is fundamental to DSL that it works on real representative data to discover structure relevant to the task in hand and thus design economic data reduction processes. To optimise a sensor package for a given discrimination task or range of tasks, data must be available to allow such optimisation.

One such task was to design camera filters and photographic processing to enable certain classes of vegetation to be discriminated. The system used four Hasselblads mounted in an aircraft (initially an autogiro) to detect areas of disturbed ground.

Representative data was required at relatively high spectral resolution in order that the filtering possibilities could be examined in detail. Extensive trials were undertaken with a Plessey grating spectroradiometer and a data base established in the DSL system.

Figure 5 shows DSL displays of the raw data and of various stages in its calibration and transformation (DSL interfaces A and B).

Although this data was also used for the evaluation of features suitable in a non-photographic system, the interest here lies in the design of the filters for the cameras. The system was used to incorporate the practical feature constraints represented by obtainable interference filters and film characteristics. Features derived within these constraints would thus be immediately implementable. Several different filter sets were designed for different subtasks.

Processing consisted of creating a colour composite photographically, thus approximating to a linear transformation of the feature space to produce maximum contrast between desired classes [24, 25].

Figure 6 shows cluster plots obtained during the feature selection procedure for a two class vegetation problem.

Work is now under way in applying these techniques to the selection of filter packages for special-purpose wide-area surveys, notably in West Africa, and also for selection of MSS bands for processing.

6. THE CERES SYSTEM

The DSL in its present form is primarily an R & D facility, and concentrates upon its role as a design tool. Its capability for operational image processing is secondary.

To meet the operational image processing requirement a modular image processing system is in an advanced state of development. The system (CERES is a joint development, funded equally by the Plessey Company and The British Government) is intended for operational processing and incorporates interactive design facilities as necessary to support such processing.

The design concept is dominated by the use of reconfigurable modules to provide a substantial range of system costs and capabilities in the examination, enhancement and classification of photographic and digital tape imagery.

As development proceeds sophisticated modules will become available implementing many of the features of the DSL, and including spatial and temporal processing in addition to the basic multispectral capability. This upgrade capability is perhaps the most important factor from the user point of view, as the technology is moving very rapidly.

7. RELEVANCE TO SPACELAB

The usefulness of Spacelab in gathering remotely-sensed Earth observation images lies not only in the information derived directly from that data, but also in the proper use of the uniquely flexible and intelligent activities possible on board. These make it possible to gather relatively wide ranging data sets adequate for the design of very much more specific sensing and preprocessing packages on board subsequent unmanned platforms.

In particular, a real ability to understand and optimise the sensors and processing for individual tasks offers a capability for remotely switched sensor and preprocessing packages on board satellite platforms. This would allow economies in the down-link by means of a substantial task-dependent data reduction.

In collaboration with the Geography Department of the University of Reading we have submitted three suggestions for experiments of this nature with Spacelab.

- (a) The first is concerned with the discrimination and assessment of high-value small-plot crops (e.g. paddy rice, irrigated crops). Analysis of ground and air reflectance samples by DSL, together with use of Skylab imagery to assess atmospheric effects will result in selection of a range of optimised film-filter combinations. Spacelab photographic images gathered with these filters would be analysed and compared with simultaneous ground truth to evaluate optimality and re-optimize.
- (b) The second is similar in form to the first, but using an in-flight switchable MSS scanner in Spacelab (with relatively high spectral resolution). This would be directed at the problem of soil moisture levels on a subregional scale.
- (c) The third is an extension of (b) to include a multisensor capability in which, e.g. passive microwave radiometer data is integrated into the data base and joint features are sought. The monitoring of soil moisture levels is a difficult task and does seem to call for the multisensor joint-feature approach. The DSL has been used with success in designing joint radar-infrared sensing packages in the past.

All three of these suggestions aim at deriving task-dependent sensing packages, and task-dependent preprocessing where appropriate.

The way forward with the very high data quantities represented by image data is through drastic data reduction as early as possible. This will, in itself, allow more sophisticated measurements to be made. There is, of course, no reason why this approach should be limited to spectral or multiband information, and the Company is working on the extension of this concept into the spatial domain, where a bewildering variety of image transforms are available. Extension to the time domain is at present a ground-based activity, but one of very considerable significance nevertheless.

8. ACKNOWLEDGEMENTS

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(Presented at the 6th Eurospace Conference, Monte Carlo, on 13-16 October 1975.)

MONITORING FROM SATELLITES

Concluded from page 186]

- (d) Saving could be made on clean-up costs.
- (e) Damage could be prevented.

These savings are quantifiable benefits, but they accrue to different categories of people who must be taxed to pay for the service or money recovered from the polluter. How this is done will profoundly affect the actual 'realisability' of the potential benefits. In short, if there is no framework to 'capture' the benefit it will either 'escape' or be regarded as a general social benefit to which no precise monetary value can be assigned.

These become very complex matters, affecting situations that are already technically complex and with many ramifications in science, technology, economy, social sciences and politics.

However, no-one can say that the space programmes are without impetus. So much has been done, as it were, on spec., that we can be reasonably confident that much of the potential of environmental monitoring by satellites can be realised in a reasonably short space of time.

ACKNOWLEDGEMENT

Some of the background for this paper arose from a study of the possibilities satellite monitoring carried out for the Monitoring Assessment Research Centre, Chelsea College.

ESA NEW EARTH RESOURCES DATA

ACTIVITY

The Council of the European Space Agency has approved a new programme, Earthnet, in which ESA will be responsible for centralising and coordinating European activities in the field of Earth resources satellite data reception, preprocessing, distribution and archiving.

A key objective of Earthnet is to provide access for European users to data from NASA satellites (Landsat, Seasat, Nimbus-G, Heat Capacity Mapping Mission) for the remote sensing of Earth resources and environment. Experience thus gained will enable European users to define their requirements for future remote sensing satellite programmes.

The first two elements of Earthnet will be:

- (i) integration into the new network of existing data reception and system preprocessing facilities at Fucino (near Rome);
- (ii) utilisation by the new system of ESA's computerised data centre at Frascati (also near Rome) and its associated information retrieval network, RECON, to disseminate catalogue information on available remote sensing satellite data.

The Council authorised the Agency's Director General to sign an agreement with Telespazio for the incorporation of the latter's Fucino station in Earthnet. ESA will use Fucino and a Swedish station for receiving data from the American satellite, Landsat. (Fucino will also be used by ESA for the control of orbital operations of its communications satellite OTS due to be launched next year).

APPENDIX B

3rd August
1977

BHATIA OR M. HERRERA RECENTRE OTTAWA

PO 2509 ARRIVED IN ENTIRETY STOP PO 2510 ANEROID BAROMETERS
RECEIVED BUT AWAITING FOR CLINOMETERS AND BRUNTON COMPASSES AND
PENETROMETER STOP REPEAT CLINOMETERS MISSING OR SUBSTITUTED FOR
BAROMETERS STOP PO 2511 DENSITOMETER NOT RECEIVED AS YET STOP
REGARDING 2508 MINI ADDCOL VIEWER ALSO RECEIVED BUT GRATEFUL IF YOU
COULD ARRANGE THAT SUPPLIERS IMMEDIATELY MAKE AVAILABLE PROPER MANUAL,
THAT IS LEAST ONE SHOULD EXPECT FOR EQUIPMENT COSTING OVER 20,000
DOLLARS STOP SORRY FOR THE DELAY MEMBERS IN THE FIELD AND SOME
CONFUSION AT OUR END BUT APPRECIATE THE ASSISTANCE YOU HAVE RENDERED
STOP ENDS

MASCARENHAS

Prof. A. C. Mascarenhas, Director, Bureau of Resource
Assessment and Land Use Planning, University of Dar es
Salaam, P. O. Box 35097, DAR ES SALAAM.

Tel. No. 53538

APPENDIX C

UNIVERSITY OF DAR ES SALAAM

P. O. Box

DAR ES SALAAM — TANZANIA

Telephone No:

Telegrams: UNIVERSITY
DAR ES SALAAM

Our Ref: SEM 2

Your Ref:



5th September, 1977

There will be a Remote Sensing Familiarization Workshop held at the University of Dar es Salaam, Bureau of Resource Assessment and Land Use Planning (BRALUP), on 12th September 1977. Because of the constraints of space it is only possible to invite a limited number of people at any one time. Invited participants are requested to arrive at the BRALUP building, Room 304.

The purpose of the workshop is to familiarize institutions in Tanzania with aspects of this new and growing technology and its application in Tanzania. In the latter aspects, we will be spending a considerable part of the time reviewing the progress of on growing work for Rukwa Region which is being undertaken by BRALUP. Attached is a programme for the day. Further details can be obtained from Mr. I. S. Kikula. Direct telephone number is 53538 or 53611 - Ext. 553.

We hope you can come.

Yours sincerely,

A handwritten signature in dark ink, appearing to read 'A. C. Mascarenhas', is written over a light-colored background.

Prof. A. C. Mascarenhas
DIRECTOR - BRALUP

BUREAU OF RESOURCE ASSESSMENT
AND LAND USE PLANNING

P R O G R A M M E

A. MORNING SESSION

- | | |
|---------------|------------------------------------------------------------------------------------------|
| 9.00 | Introduction by Prof. A. C. Mascarenhas |
| 9.45 | LandSat: Data Acquisition and Analysis with
Reference to Tanzania - Prof. R. Pitblado |
| 10.45 - 11.00 | COFFEE BREAK |
| 11.00 - 12.00 | Application of LandSat Data to Tanzania
- Dr. R. B. King |
| 12.00 - 1.15 | LUNCH BREAK |

B. AFTERNOON SESSION

- | | |
|-------------|------------------------------------------------------------------------------------------|
| 1.15 - 1.50 | LandSat Data and Vegetation Studies with
Reference to Rukwa Region - Mr. Idris Kikula |
| 1.50 - 2.20 | Remote Sensing on Hydrological Aspects
- Mr. James Ngana |
| 2.20 - 2.50 | Assessment of Rukwa Survey Using LandSat
Data - Dr. R. B. King |
| 2.50 - 3.10 | LandSat Data and Socio Economic Information
- Mr. A. Sporrek |
| 3.10 - | Conclusion by Prof. A. C. Mascarenhas |

- End -

LANDSAT: SOME PRINCIPLES OF DATA ACQUISITION AND ANALYSIS

J. Roger Pitblado, Ph.D.

In 1972 the United States National Aeronautics and Space Administration (NASA) launched the first in a series of satellites in their Earth Resources Technology Satellite programme (ERTS). ERTS-1, later to be named LANDSAT-1 was joined in space by the LANDSAT-2 satellite in 1975. Soon to accompany them later this year or early in 1978 will be LANDSAT-C, and later still will be LANDSAT-D, scheduled to be launched in 1981. (In this programme planned satellites are given an alphabetic designation, e.g. LANDSAT-B, which, upon successful launching, are then changed to a numerical designation, e.g. LANDSAT-2).

The ERTS or LANDSAT programme was originally conceived as an experimental programme to determine whether earth phenomena could be adequately sensed or measured in a repetitive way from a remote platform in space, a satellite. The answer to that basic question is a qualified "Yes". Indeed, many investigators around the world speak of LANDSAT as an operational mode of remote sensing (as opposed to experimental), although NASA does not yet make that claim.

This paper only indirectly addresses itself to the question of whether the LANDSAT programme can now, in 1977, be considered operational or not. Rather, it deals with the basic principles of LANDSAT data acquisition and analysis. Naturally, given the allotted time, these principles are only briefly sketched. In terms of analysis, emphasis is placed on those techniques that may be considered to be relevant in Tanzania. That is, the discussion will concentrate on techniques of LANDSAT data analysis that can be or are employed in Tanzania today.

Data Acquisition

LANDSAT-1 and -2 were placed in a near-polar, sun-synchronous orbit at a distance of approximately 900 km from the earth. The orbital period is 103 minutes and 14 orbits of the earth are completed each day. As the earth rotates, successive orbits make different ground tracks such that sensing is repeated over the same ground track every 18 days. In this way it is theoretically possible to obtain repetitive coverage in 18-day cycles of the earth's surface from 81°N to 81°S, inclusive. In fact, while LANDSAT-1 and LANDSAT-2 were both operational the amount of repetitive coverage in some parts of the world was increased to less than 18 days. Today only LANDSAT-2 is in operation.

On board LANDSAT-1 and LANDSAT-2 are two primary sensors. Together the Return Beam Vidicon (RBV) television system and the Multispectral Scanner (MSS) system could sense reflected radiation from the earth's surface in specific spectral bands in the visible and near (optical) infrared ranges of the electromagnetic spectrum. LANDSAT-C is designed to also sense in the far (thermal) infrared range. Several difficulties have made the RBV systems of LANDSAT-1 and -2 inoperative. Therefore the remainder of this paper deals with the acquisition and analysis of MSS data.

The MSS system employs an oscillating mirror, an optical system, and fibre optics to view a strip of land 185 km wide. This continuous swath of terrain is scanned (using the oscillating mirror) by the MSS which picks up or senses reflected earth radiation. The scanning beam is split into 6 lines or narrow strips to improve resolution. Using the fibre optics array, sensed radiation in each of the 6 strips is separated by 4 detectors (i.e. a total of 24 detectors in the fibre optics array).

Each of the 4 detectors in the set of 6 is photosensitive to a specific range of wavelengths or bands of the electromagnetic spectrum. The MSS wavelength ranges are labelled Band 4, Band 5, Band 6, and Band 7 to distinguish them from the somewhat similar wavelength ranges, Band 1, Band 2, and Band 3, of the RBV system. The specific wavelength ranges of the MSS system are as follows:

Band 4	500 - 600 nanometres	(green/yellow)
Band 5	600 - 700 nanometres	(red)
Band 6	700 - 800 nanometres	(near infrared)
Band 7	800 - 1100 nanometres	(near infrared)

(1 nanometre is equal to 1×10^{-9} metres)

The MSS system measures the intensity of these light signals on a scale of 0 to 63 and transforms them into electrical signals. This information can be telemetered to earth in real time (i.e. instantaneous transmission) if the satellite is within the range of a ground receiving station. Presently there are three ground stations in the United States, two in Canada, and one each in Brazil and Italy. There are a number of other ground stations in the planning stage, including the one in Zaire. If the satellite is not over a receiving station the data can be recorded on the satellite's tapes and then telemetered to earth later.

At a LANDSAT ground station the data received from the satellites is stored electronically. At the station the data is also "scened". Recall that the MSS scans continuously a swath of terrain 185 km wide. These continuous swaths are then subdivided with a small amount of overlap into scenes 185 km x 185 km. Scenes or images can then be purchased from appropriate agencies. African imagery, for example, is obtainable from the EROS Data Center in Sioux Falls, South Dakota (USA), a section of the US Geological Survey.

The LANDSAT imagery is available in several standard forms. In the first instance one can purchase scenes in digital form on what are known as computer compatible tapes (CCT). Alternatively, there are many photographic products. The digital information may be altered electronically (e.g. with an electron beam image recorder) to produce a photographic negative. This can be done for each of the four separate bands. Such a negative can then be used to produce film or paper prints at various scales. Another very useful product is a colour composite. These are produced by combining black-and-white (B&W) transparencies in three bands onto colour film, each band being exposed to a different coloured light or filter. The resulting product is known as a false-colour composite (FCC) because the colour rendering is not what the eye would perceive if looking at the object being sensed. For example, very green and dense vegetation appears red in the FCC.

A list of the standard EROS Data Center products is provided below. The list indicates the type of products that are available, their scales, and their approximate costs in Tanzanian shillings at the time of writing this paper. (Note: FCCs are not automatically produced for each and every LANDSAT scene. If a colour master has to be produced the purchaser must add the one-time fee of approx. Sh. 413/-).

1: 3.7M	- film negative (B&W)	Sh. 50/-
	- film positive (B&W)	66/-
1: 1M	- film negative (B&W)	83/-
	- film positive (B&W)	83/-
	- film positive (FCC)	124/-
	- paper (B&W)	66/-
	- paper (FCC)	99/-
1: 500,000	- paper (B&W)	99/-
	- paper (FCC)	207/-
1: 250,000	- paper (B&W)	165/-
	- paper (FCC)	413/-
CCT		1652/-

Data Interpretation

As with air photographs and other remotely sensed imagery there are many keys or characteristics that are used in the interpretation of satellite imagery. Perhaps the most important principle of interpreting LANDSAT imagery is the process of identifying spectral signatures. This

process takes advantage of the multispectral character of LANDSAT data and can be illustrated with the following simple description.

Virtually every element in our environment, rocks, soil, water, vegetation, etc., radiates or reflects energy. For the most part, this energy is either reflected solar energy or thermal radiation. But each element of the environment radiates or reflects a different amount of energy along the electromagnetic spectrum. A plot of intensity of radiation versus wavelength is termed the spectral signature. The plot of the spectral signature of, say, crop A will likely be different from the plot of the spectral signature of crop B (see Figure 1).

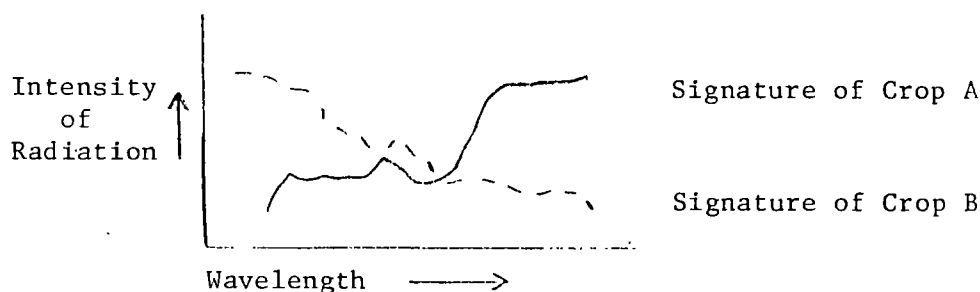


Figure 1. Hypothetical spectral signatures of crops A and B.

In Figure 1, the peak and mean energy of the two spectral signatures are approximately equal. If a wide-band sensor were used to examine these two crops they would look alike. However, if two or more narrow-band sensors were employed, the signatures of the two crops could be differentiated. In the multispectral sensing system of LANDSAT, four relatively narrow-band sensors are employed and have been previously described. As a broader example, vegetation is highly reflective of infrared radiation (Bands 6 and 7) but low in the area of blue/green wavelengths (Band 4); but water is close to being the reverse of the vegetation signature.

In principle, the objective of multispectral analysis is to match a particular spectral signature with a particular element of the environment that is under study. This assumes that spectral signatures are constant under all conditions, but this is not the case. With crops again as examples, subtle variations in signatures arise depending on their health and state of growth, soil moisture conditions, soil reflectance characteristics, etc. In some instances this makes interpretation difficult. On the other hand, it does also enable one to make predictions about probable yields, identify moisture stress, detect disease, and so on.

In practice, and particularly when dealing with LANDSAT imagery, the preciseness alluded to in the preceding paragraphs is rarely attained. This arises from the fact that one is not dealing with stable conditions and resolution characteristics of the imagery (to be dealt with later in the paper) leads to difficulties in signature discrimination. Even so, provided ground truth is available for control, these unstable signatures can be very useful.

There is now quite a wide range of techniques available for the interpretation of satellite imagery. Indeed, the range is rapidly increasing and making it difficult to keep up with the advances. For want of a better classification, the techniques that will and are now being employed in Tanzania can be discussed under three headings: visual interpretation, image enhancement, and digital analysis.

Visual interpretation is pretty much self-explanatory. The interpreter examines the photographic LANDSAT products with the naked eye or possibly with the aid of a magnifying glass or instrument. The keys to interpretation are similar to those used for air photo interpretation: tone or colour, shape, pattern, texture. Unlike the interpretation of air photographs, satellite imagery is not amenable to stereoscopic viewing. For many this disadvantage is outweighed by the multispectral character of the data and the fact that an overview, the "big picture", is provided of the terrain under investigation.

Image enhancement takes advantage of the subtle density* differences that are characteristic of film emulsions but which are not readily apparent to the human eye. For example, the human interpreter can identify a significant number of gray shades on film if they are contiguous or close together. But the matching of similar shades of gray when they are quite widely separated on a piece of film is often impossible. Image enhancement allows the interpreter to highlight those levels of density which he is most interested in. The most common forms of image enhancement are additive-colour and density slicing.

* The density (D) of a photographic film can be expressed in terms of its transmittance (T) by the equation:

$$D = \log 1.00 / T$$

If a film is completely transparent, T is 100% and therefore $D = \log 1.00 / 1.00 = 0.00$, where $\log 1.00 = 0.00$.

When T is 50%, $D = \log 1.00 / 0.50 = 0.30$, and so on.

The D range of average film is from about 0.05 to slightly over 3.00.

Although not directly, additive-colour enhancement has already been referred to. The false-colour composites that are part of the standard products list of the EROS Data Center are additive-colour enhancements. They were produced by taking several B&W images and projecting them in register (i.e. superimposed) through different colour filters as illustrated in Figure 2.

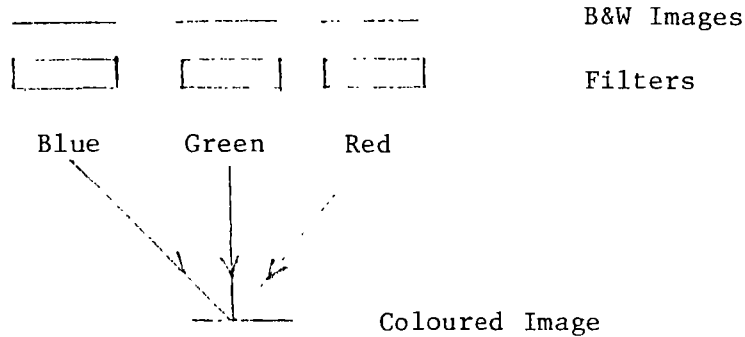


Figure 2. Line diagram demonstrating the principle of additive-colour enhancement.

But the standard EROS product is not subject to the interpreter's control. With appropriate equipment - photographic, electronic, or optical-mechanical - such control can be given to the interpreter who will then be able to highlight those densities that are of most interest to him. The resultant false-colour images so produced are those of the interpreter's discretion as the additive-colour enhancements are a function of the densities of the original B&W images, the colour of the filters used, and the relative intensity of the light sources for the separate multispectral images.

Different density levels of one image may be separated from each other by the technique of density-slicing enhancement. For example, if one knew that a certain crop appeared on Band 7 film within a density range of, say, 1.20D and 1.40D, then using density-slicing this particular D-range could be isolated and its distribution over the original film noted. A second D-range, a third D-range, and so on could be separated also. The areas within each of these D-ranges, i.e. area equidensities, can be coloured separately then reconstituted into a single false-colour enhancement.

Enhancement by density-slicing can be achieved either by electronic or photographic techniques. The photographic process can be used here to illustrate the principles. The original positive (e.g. a Band 7 film positive) in Figure 3 is made up of three levels of densities. These densities can be reproduced onto high contrast photographic film by systematically increasing the exposure times. In the illustration, three negatives are produced: negative A contains an opaque zone corresponding to density level 1, and a transparent zone corresponding to density levels 2 and 3; when

the exposure is increased, negative B contains an opaque zone corresponding to density levels 1 and 2, and a transparent zone corresponding to density level 3; and finally with a further increase in exposure, negative C contains an opaque zone corresponding to density levels 1, 2, and 3, with no transparent zone at all.

If one were interested in isolating areas of the original positive which fell into density level 2, the next step would be to produce a positive of negative B. The result would contain a transparent zone in the areas of density levels 1 and 2, and an opaque zone in the area of density level 3.

The final step in the process requires that negative A and the positive of negative B be printed together in register. The result is an equidensity or density-slice highlighting density level 2 in contrast to all other density ranges.

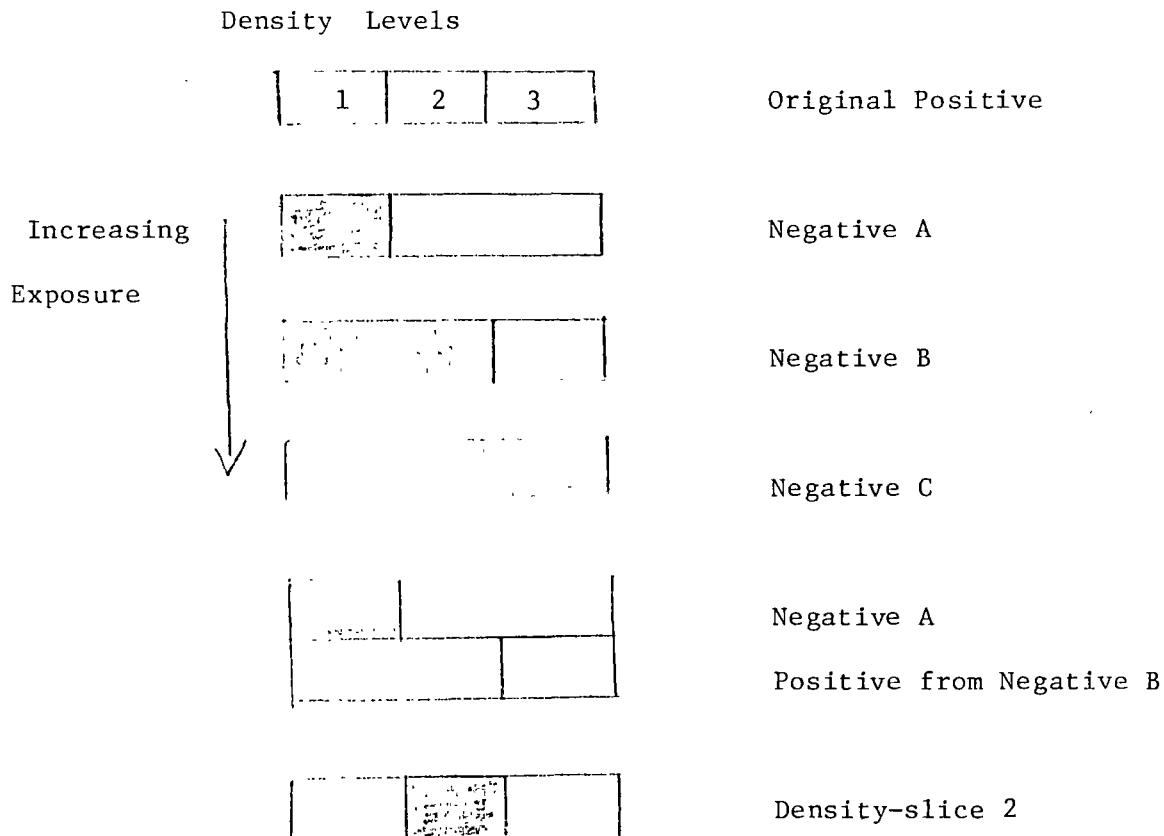


Figure 3 Density-slicing process using the technique of photographic masking.

The photographic procedure that has just been described illustrates the principle of density-slice enhancement using the technique of photographic masking. It is a rather cumbersome procedure, especially when many D-ranges are being investigated. The alternative, recommended photographic procedure for density-slicing employs the equidensity film produced by Agfa-Gevaert, agfacontour film. With this film, area equidensities can be produced in a single, simple process using conventional photographic copying procedures. The technique is accurate and repeatable. Although not as fast as electronic means it is certainly less expensive.

While the visual interpretation and image enhancement techniques described are extremely useful, they do not take advantage of all of the data that LANDSAT produces. They do not do so because it is impossible to "cram" all of the data from a LANDSAT scene into such a relatively small space as a photographic product. Digital analysis techniques try to overcome this disadvantage by analyzing the LANDSAT multispectral data at the level of a pixel.

Recall that the MSS system breaks the scanning "beam" into 6 lines. Each of these lines represents a ground width of about 79 m. As the MSS mirror oscillates across the LANDSAT swath 3240 readings are made. As the width of the swath is 185 km or 185,000 m, this means that readings are taken every 57 m apart. In effect, one obtains a reading in each of the four MSS bands for a ground area of 57 m x 79 m. This small area is referred to as a pixel, short for "picture element". In a single LANDSAT scene there are 3240 x 2340 (i.e. 7,581,600) pixels (Figure 4). But for each pixel there are four pieces of multispectral information. Therefore, there are 30,326,400 bits of information or data connected with each LANDSAT scene! Little wonder then that investigators have turned to the use of high-speed computers to aid in the interpretation of LANDSAT imagery.

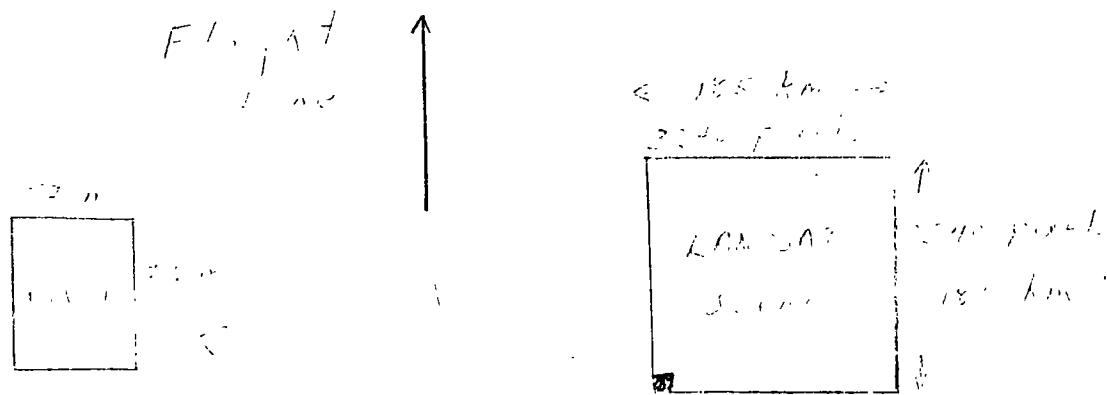


Figure 4. Schematic Representation of LANDSAT Scene and Pixel Ground Coverage.

The pixel configuration described above and illustrated in Figure 4 is characteristic of LANDSAT-1 and LANDSAT-2. It provides for a limit of resolution of approx. 0.7 ha. LANDSAT-C will be superior in resolution as the length of the pixel will be reduced to 30-40 m.

In digital image analysis, one approach to LANDSAT data interpretation is to allow the computer to examine each pixel, set up criteria by which pixel groups or clusters are defined, and then classify the pixels according to their spectral signatures with these rules. In this approach neither the computer nor the interpreter knows before-hand what a class represents in terms of earth phenomena. When the computer has made its classification (using one of many algorithms) it is up to the interpreter to match the classes with earth phenomena - not always an easy task. This is known as unsupervised classification.

An alternative approach allows the interpreter to "show" the computer that a particular pixel or group of pixels is miombo woodland; that another is upland forest; and so on. Each of these pixels or pixel groups will have a characteristic spectral signature that the computer will be able to identify from the digital information supplied by the CCT of a LANDSAT scene. So trained, the computer can then be instructed to code all pixels having the characteristic signatures - i.e. the example classes noted above and probably a class denoting "Other". This procedure is referred to as supervised classification.

There are a number of digital image analysers or processors capable of handling LANDSAT data produced by such American companies as General Electric, International Imaging Systems, and Bendix. The Plessey Co. of Great Britain will soon be marketing an image processor. All are very expensive!

For the land resources inventory of Rukwa Region being conducted by BRALUP, use is being made of the system known as the IMAGE 100. This hardware/software package was developed by the General Electric Co. for and under the specifications of the Canada Centre for Remote Sensing. This system, as with most others, can only cope with an array of 512 x 512 pixels at a time (i.e. 1/29 of the area of a LANDSAT scene). The IMAGE 100 display is a high-quality TV screen from which colour slides or prints can be made. Additional hard copy output consists of computer print-outs and maps, some of which will be shown later today.

Final Comments

This presentation of LANDSAT data acquisition and analysis principles has largely been text-bookish in nature. It was designed to be so in order to provide some common base for further deliberations during this workshop. Noticeably lacking is a discussion of Applications, but this will be taken up by the papers which follow.

Suffice it to say, LANDSAT imagery is being employed in many parts of the world as an aid to general land resources surveys, crop inventory and monitoring, flood hazard prediction, water pollution monitoring, soil moisture assessment, geological survey, and forest fire assessment and control. This is but a short list of the many uses to which LANDSAT imagery is being put.

As an aside, the news media have recently been carrying reports on the proceedings of the UN Conference on Desertification being held in

Nairobi. Of significance for us here today is the item that Argentina, Peru, Chile, and Bolivia are considering the joint establishment of a centre that would use LANDSAT imagery and other satellite data to monitor the arid regions of these countries (somewhat similar to the joint project agreed to last January by Afghanistan, India, Iran, and Pakistan).

In the introduction to this paper reference was made to the question of whether the LANDSAT programme, now after five years of experimentation, can be considered operational. Perhaps this is a moot question with reference to Tanzania - the experiences to date just are not adequate to respond to that question. Surely the test comes from trying to apply the technology and thereby establishing the limits of what satellite imagery can and cannot do. Some of these limits to the use of LANDSAT imagery in Tanzania are now being explored by BRALUP and therefore their preliminary results to be reported in this Workshop should be of extreme interest.

Acknowledgements

The assessment of LANDSAT imagery for use in Tanzania is a project jointly sponsored by BRALUP and the International Development Research Centre, Ottawa, Canada.